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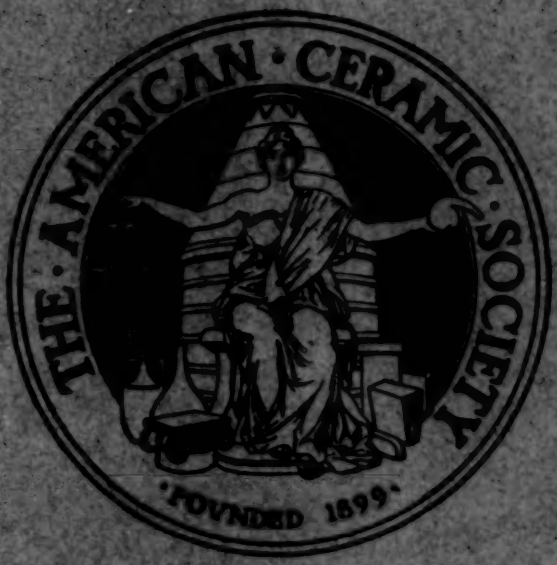

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THE ELECTRICAL BEHAVIOR OF GLASS AT ROOM TEMPERATURE*

By E. M. Guyer

ABSTRACT

New instruments and equipment are described for the measurement of the electrical conductivity of glass at room temperatures. The accuracy of the method is discussed and certain precautions are specified for this type of measurement. A short review is given of the results of measurements with such equipment on a series of glasses. In particular, experiments are described on the effect of (1) chilling, (2) prolonged heat treatment which produces an actual separation of phases, (3) mechanical strains, and (4) superposed radio-frequency currents on the conductivity of the glass at room temperature. In conclusion, it is pointed out that the results of these measurements indicate that the electrical behavior of glass at room temperature is of importance.

I. Introduction

Certain experiments are described which were initially undertaken at Corning for the general study of glass properties. The particular electrical property of the investigation was the direct-current electrical resistance at ordinary room temperatures. Investigations in this region have been somewhat neglected because of the difficulty and uncertainty heretofore experienced in measuring the very small currents which can be made to flow through cold glass with reasonable applied voltages, since the specific resistivities are of the order of 10^8 to 10^{16} ohms.

Since the method devised for measuring the direct-current resistivity of glass at room temperatures is new and possesses important advantages over previous systems, a discussion of the instruments involved and the technique of this type of measurement will be given before reporting the results.

II. Modern Instruments

In the recent past direct-current electrical conductivity measurements on glass at room temperatures required the use of some form of highly sensitive galvanometer or else of an electrometer. Either of these devices when pushed to the limit of its sensitivity becomes a very delicate and often a highly unstable instrument.

(1) Pliotron Ever since the advent of the three-electrode vacuum tube which revolutionized radio there has been, theoretically at least, the possibility of developing a stable electrical measuring instrument of electrometer sensitivity. This invention made such an electrical measuring instrument possible because in the vacuum tube an electric current can be started, stopped, or caused to flow with any desired strength between definite maximum and minimum values by the control of a minute electrical charge on the grid or intermediate electrode. This remarkable feature of the device, namely, the control of an electric current by an electric charge, promised almost unlimited power amplification. That this promise was not at once realized but required many years of development to reach its present state of fulfillment was due to the presence in most vacuum tubes of seven sources of leakage currents at the most vital spot in the mechanism, namely, the grid. These difficulties, however,

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have at last been largely overcome in at least one tube known as the FP54 pliotron, manufactured by the General Electric Company.

The use of the pliotron for electrical measurements on glass at low temperatures involves the important advantage of increased sensitivity without loss of accuracy by instability. With a single pliotron operating into a 5 times 10^{-10} ampere per millimeter galvanometer in its plate circuit and provided with a 10^{10} Ω input resistor, currents of the order of 10^{-15} amperes can be detected and currents of the order of 10^{-13} amperes can be measured with an accuracy of $\pm 1\%$. If very high sensitivity is necessary, two matched pliotrons can be arranged in a bridge circuit in such a way that the grid current in one neutralizes that in the other, and under these conditions currents of 5 times 10^{-18} amperes can be detected. This corresponds to a flow of only about 30 electrons per second. Where vibration is bad enough to preclude the use even of a relatively insensitive galvanometer or where a portable instrument is desired, additional stages of amplification may be employed working into a micro-ammeter.

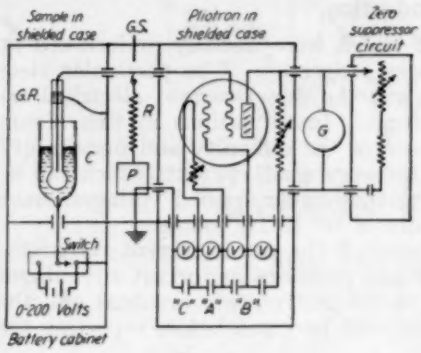

FIG. 1.

The pliotron also has great flexibility. Merely by changing the input resistors the instrument will measure currents ranging from the very minute ones mentioned above up to currents ordinarily measured with an ammeter. This is especially useful in the case of a material such as glass in which the variations in resistance from one temperature range to another may be of the order of 10^{16} fold.

(2) Insulation and Shielding While the pliotron makes the construction of a highly sensitive direct-current amplifier a relatively simple task, the problems of insulation and shielding are, of course, as important as ever.

III. Assemblage

In Fig. 1 the general arrangement of apparatus is shown together with a wiring diagram of one form of circuit which has been used with success at Corning Glass Works. The set-up is roughly divided into three distinct sections. At the extreme left is a shielded case in which the sample of glass under test is supported on a suitably insulated stand. Beneath this is the main battery for the application of electromotive force to the sample. The sample case communicates through a completely shielded housing with the central cabinet in which the pliotron itself is located above its associated power supply batteries.

The pliotron case is not only electrically shielded but is sealed up air tight and the tube is mounted over a shallow dish in which drying agents are kept as a precaution against external leakage along the surface of the glass.

The voltmeters, each marked (V), which indicate when the pliotron

is being operated with the proper potential on the plate, the space charge grid, and across the filament, are mounted on a control panel with the necessary switches, rheostats, and potentiometers. Essentially these meters serve to check up on the voltage of the "*A*," "*B*," and "*C*" batteries, respectively.

The "zero suppressor" circuit and galvanometer are shown at the right. Reference to the wiring diagram shows that with the main battery switch turned to the right both the inner and outer mercury electrodes of the glass bulb sample are connected to the grounded shield. As soon as this switch is turned to the left, however, the electromotive force of the battery is impressed on the glass sample, the resulting current which flows through the glass returning to the opposite side of the battery through the input resistor, R (order 10^6 to 10^{10} ohms), and the potentiometer, P. It is of the utmost importance that the conductor connecting the upper or inner electrode of the sample to the ungrounded end of the input resistor and to the control grid of the pliotron be insulated as perfectly as possible. At Corning it is the practice to make this conductor a stiff brass rod and to support it at its extremities by Pyrex insulators of very long and carefully tested leakage path. Obviously the stray resistence of this lead to ground must be high compared to the volume resistivity of the glass to be measured.

Any current which flows over the surface of the sample instead of through the glass is intercepted by the guard ring, *GR*, and returned to the grounded shield without passing through the input resistor. Since the input resistor is in series with the glass and the battery the same current flows through all three. The voltage drop across the known resistance may be applied to the control grid of the pliotron simply by opening the grounding switch, *GS*.

IV. Operation

In making a measurement the procedure is as follows: The tube is turned on, all voltages indicated by the meters on the control panel are adjusted to their proper values, and the instrument is allowed to run anywhere from twenty minutes to two hours to reach thermal equilibrium with its shielded case and to allow electrostatic charges on the walls of the tube to come to a steady state. The deflection of the plate circuit galvanometer is reduced to zero by adjustment at the suppressor circuit. The pliotron is then ready for operation. Before proceeding with the measurement, however, the glass sample, which presumably has been kept in a shielded constant-temperature cabinet for a sufficient time to reach the temperature of its surroundings, must be tested to make sure that it is electrically neutral at the beginning of the measurements. With the sample connected directly across the input terminals of the tube, the control grid is ungrounded and the galvanometer deflection observed. If there is no deflection the sample of glass is unpolarized and the operator is free to proceed with the measurements. Should there be an initial galvanometer deflection, on the other hand, the electrodes on the sample must be connected together and left so until the initial deflections are no longer produced when the control grid is ungrounded. If repeated tests continue to show galvanometer deflections which do not diminish with the time, the difficulty is probably due to a thermal or an electrolytic electromotive force somewhere in the input system.

The measurement of the conductivity is then made by switching on the battery and observing the deflection of the pliotron plate circuit galvanometer. In general, the most accurate results are obtainable by a so-called null method in which, instead of recording the galvanometer deflection, the galvanometer is brought back to zero by balancing or neutralizing the electric charge on the pliotron grid with the help of the potentiometer shown in the input circuit. When this balance is achieved, the known potential impressed on the grid by the potentiometer is equal to that produced by the charge coming from the glass and passing through the input resistor. This measurement of the voltage drop, $e = iR$, across the known input resistor, R, permits the calculations of i, the current through the glass sample. Once the current produced in the glass by a known impressed voltage has been found, the resistance or conductivity of the sample can be calculated by Ohm's law.

V. Preparation of Sample

The procedure described above serves to determine the electrical resistance only, a property characteristic of the particular sample of glass tested and varying with the dimensions of the glass and of the electrodes attached to it. What is wanted, of course, is the so-called electrical resistivity of the glass, *i.e.*, the resistance per unit area and per unit thickness, which is characteristic of the glass itself and independent of the particular form of sample tested. To calculate this value we must be able to measure either directly or indirectly the average thickness of the glass between the electrodes and the area of the electrodes. Thus the form of sample used in electrical conductivity tests is of importance and if not properly taken into account may lead to great inconvenience in calculation and inaccuracy in final results. Unfortunately, however, the form of sample to be employed is often determined by other factors than convenience. With poorly conducting glasses, for example, the principal requirement is to find a form of sample which will conduct enough current to measure with obtainable impressed voltages. In such cases special procedures must be resorted to in the reduction of the measurements to standard form.

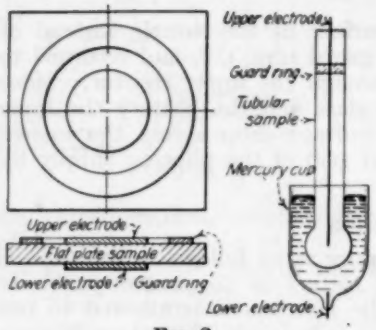

FIG. 2.

(1) Shape of Glass Sample In Fig. 2 two forms of glass samples are shown which have given good results in electrical conductivity measurements in glass at room temperature. The flat plate sample at the left is satisfactory for glasses which are fairly good conductors (10^8 to 10^{12} ohms) and permits a calculation of the resistivity from the measured resistance. As may be seen in the figure, surface leakage currents which, in general, are many times greater than the actual current through the glass which it is desired to measure are eliminated by surrounding one of the disk electrodes with an annular guard ring which is connected to ground during the measurements as indicated in Fig. 1.

(2) Electrodes Different kinds of electrodes which have been tried on this form of sample are tin foil pressed on with glycerine (the excess liquid being carefully cleaned off with xylol), mirror silvering, and silver paste painted on and fired into the glass with subsequent coats of copper from an electroplating bath. The plates have also been floated on mercury to form a lower electrode with thin concentric brass rings cemented to the top surface providing trays for an upper electrode of mercury as well as a guard ring. The fired-on silver and copper plating process, when properly carried out, seems to work as well as any of the methods and is, perhaps, the most convenient.

(3) Bulb Form for High-Resistivity Glasses For glasses with high electrical resistivity probably the best form of sample is a very thin bulb blown on the end of a tube. Mercury electrodes are easily applied by filling the bulb and submerging it in a cup. The unknown and varying thickness of the glass and the area of the mercury in contact with the glass must be calculated, however, from additional information. The electrical capacity of the glass sample, considered as a condenser, involves the area to thickness ratio of the glass just as the resistivity does. Thus, by measuring the electrical capacity of the sample with a capacity bridge or other well-known method and by dividing the capacity by the dielectric constant of the glass, the area to thickness ratio can readily be calculated. In case the dielectric constant is unknown it in turn must be measured by using a flat plate sample of proper dimensions.

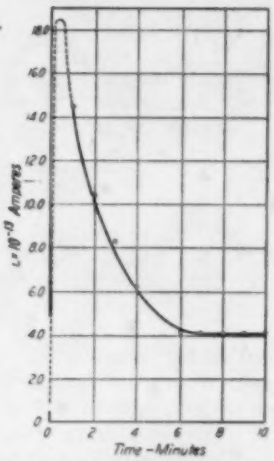

FIG. 3.—A typical charging current (glass No. 4).

(4) Results To people who are well acquainted with the complex nature of glass it is probably not surprising to learn that its electrical behavior, like so many other characteristics, is rather strange when judged by standards which have been established largely by experience with a different class of electrical conductors. Glass, in common with certain other dielectrics, exhibits electrical properties which are so strikingly different from those of ordinary metallic and electrolytic conductors that they have come to be looked upon as something abnormal, and these peculiar properties are often referred to as anomalies.

VI. Dielectric Absorption Current and Residual Charge

(1) Different Glasses Require Different Lengths of Time In Fig. 3 a curve is shown which indicates what happens when a piece of glass provided with electrodes is connected to a battery or other source of constant voltage. The current flowing in the glass is represented at successive intervals of time after the first application of the voltage. In other words, the curve represents the complete charging current characteristic of the glass. Three distinct regions are to be observed. The dotted portion, which is not plotted accurately to

scale and is added for the purpose of demonstration only, represents the first rush of electric charge into the glass at the moment of closing the battery switch. This rapid surge lasts only for a few millionths of a second, being determined by the capacity of the glass sample considered as a condenser and the dimensions and arrangements of the charging circuit in accordance with the laws of classical electrodynamics. The steep downward sloping region represents the decay of the pure capacity charging current and its merging into a so-called reversible absorption current sometimes called the anomalous charging current because it persists long after the geometrical charging current predicted by the theory of an ideal condenser has passed completely out of the picture. Finally the curve straightens out and the current passing through the glass in this stage is what is ordinarily meant by the conduction current. This figure indicates clearly that the resistance of a glass at low temperatures is of little value unless it be specified at what time after the first application of voltage the measurement is made. This is further complicated by the fact that different glasses require entirely different lengths of time to reach the steady state.

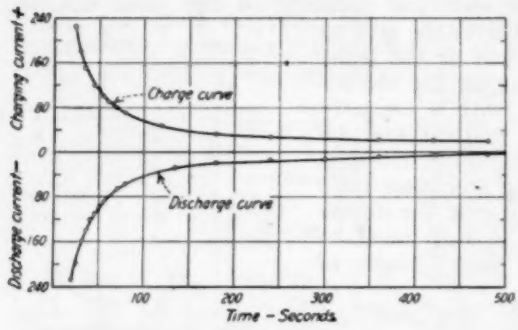

FIG. 4.

(2) Residual Charge Figure 4 shows a typical charge and discharge curve for a borosilicate glass. The curve below the time axis, which appears at first sight to be the mirror image of the upper curve, is the discharge curve showing the current which flows back out of the glass in the reverse direction after the battery has been disconnected and the sample has been temporarily short circuited. This is the so-called residual charge, first observed and investigated in Leyden jars in 1746 by Benjamin Franklin. He discovered that when such a glass jar, partially coated inside and out with tin foil, was charged to a high potential from an influence machine and then discharged and allowed to stand, sparks could still be drawn after successive intervals of waiting without repeating the charging process. As can readily be seen from the lower curve in Fig. 4 the anomalous absorption and residual charge are converse effects. The residual charge which remains in the glass after the charging battery is switched out of the circuit and even after the glass has been short circuited seems to represent a certain amount of electricity which has in some way been stored up in the glass itself (not merely on the electrodes as in a storage battery) and requires considerable time to soak out just as it did to soak in while the original charging-up process was going on.

(3) Self-Reversing Charge Figure 5 represents an interesting peculiarity of the residual charge discovered in glass by Hopkinson. He found that if, during the charging up process of a glass condenser, the applied voltage were suddenly reversed and held

that way for a short time and the electrodes were short circuited to remove the pure capacity charge, a residual charge appeared producing a current which flowed in one direction for awhile and then, spontaneously and of its own accord, turned around and flowed in the opposite direction. In the figure the current due to such a self-reversing residual charge is shown as it was observed and measured in a borosilicate glass at Corning. The current at first flows in the positive direction, but decreases rapidly in magnitude until it reaches zero. It begins to flow in the reverse direction building up to a maximum on the negative scale. It then decays in the usual manner approaching zero very slowly.

(4) Charge Flow Opposite to Battery Electromotive Force

Figure 6 shows a rather remarkable case in which a current flows through a high lead glass in the reverse direction to the electromotive force of the battery. The charging schedule in the upper right-hand corner of the figure indicates that the glass in this case was electrified for 30 seconds with a positive voltage of 225 volts. The voltage (still positive) was then reduced to $112^1/_2$ volts, and the sample was shorted temporarily and finally connected to the pliotron. In spite of the presence of the battery in the circuit the direction of flow of the current was that of the former discharge or decay of initially higher polarization for one minute. At the end of this time the reversed current had dropped to zero after which a current flowing in the opposite direction appeared and built up to a value approaching that of the final conduction current.

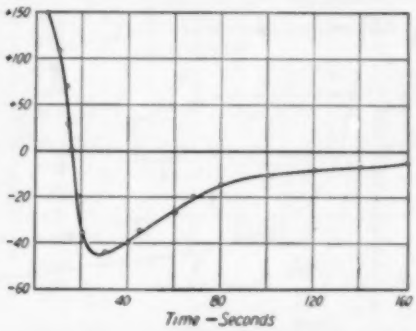

FIG. 5.—Reversal of residual charge (+ 225 volts 30 seconds, −112.5 volts 10 seconds).

(5) Effect of Past History of Glass

These spontaneous reversals of the residual charge emphasize the fact already established by the occurrence of the residual charge itself, namely, that the past history of cold glass determines to a pronounced degree its subsequent electrical behavior. Experiments recently performed at Corning indicate also that the thermal history of glass in some cases can determine its electrical behavior at room temperature in just as pronounced a manner as its electrical history.

(6) Cause for Delayed Charges

Before going on, however, to show how the anomalous charging current and conductivity at room temperature are affected in certain cases by a preliminary heat treatment of the glass, a short summary will be given of the known facts concerning dielectric absorption and residual charge.

In spite of the long list of celebrated scientists who have studied this subject, including such names as Maxwell, Lord Kelvin, Curie, Hopkinson, and many others, surprisingly little is known about the underlying cause of these delayed-charge transfers in certain dielectrics, of which glass at low temperatures is one of the most striking examples. Such theories as

have been advanced, and there are many, have all failed so far to predict quantitative results which can be accurately verified by experimental measurements over a wide range of charge and time relations. On the other hand, starting with radically different ideas of the basic mechanism of the process, several theories predict qualitatively similar results so that little choice between them is possible.

Regardless of theory, certain facts are generally accepted by the majority of those who have experimented with dielectrics, including glass.

(1) Many have shown that the anomalous absorption current and residual charge both decay in accordance with some form of logarithmic function of time.

(2) The effects of past and present dielectric polarizations have been found to obey the so-called superposition principle. That is, past and present changes in applied voltage produce changes in the polarization of the dielectric independently of each other, each voltage change producing the same change in polarization which it would have had it acted alone.

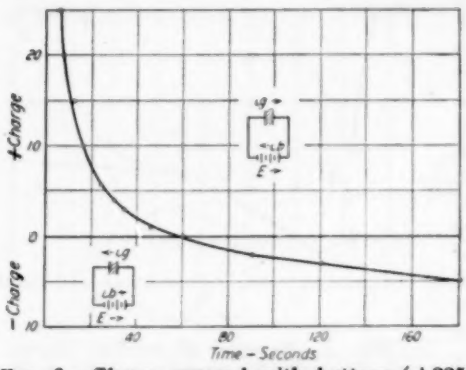

FIG. 6.—Charge reversal with battery (+225 volts 30 seconds, +112.5 volts during reading).

(3) Hopkinson has pointed out that changes in either temperature or applied voltage produce variations of similar magnitude in the instantaneous value of both the anomalous charging current and the final conduction current. Temperature changes also produce pronounced variations in the time rate of variation of the absorption current, *i.e.*, the higher the temperature the more rapidly the absorption current decays and merges into the final conduction current.

(4) The work of Curie and Wilson has shown that changes in the voltage gradient produce variations in the instantaneous current through dielectrics such as glass but do not affect the time rate of change of this current, *i.e.*, the steepness of the anomalous charging current curve is not changed but its height is altered.

(5) From the standpoint of practical applications perhaps the most significant fact, demonstrated by numerous experimenters, is the dependence on dielectric absorption and residual charge of the electric power losses in glass and other dielectrics in alternating electric fields which determines to a considerable extent the life and performance of present-day insulating materials. Whitehead and his collaborators have even calculated these power losses, in some cases, from direct-current measurements of anomalous charging current.

VII. Dependence of Electrical Behavior of Glass at Room Temperature on Its Thermal History

Measurements of the absorption current and final conduction current were made at Corning on a series of glasses which had been prepared by a

prolonged heat treatment at a temperature just above the annealing point to see what effect, if any, different degrees of separation of the glass into different phases would have upon its subsequent electrical behavior at low temperatures. The results of this series of measurements are shown in Fig. 7. Rather than show the entire family of charging curves obtained for each glass (one curve corresponding to each time of heat treatment), a representative point was taken from each curve of a family and these representative points are shown to be plotted as a function of the time of heat treatment. Glass No. 1 is a lead-borosilicate glass; No. 2 and No. 3 are soda-borosilicate glasses.

The charging current is seen to change rapidly in the case of each of the glasses tested for short periods of heat treatment after which there is practically no further variation regardless of how long the glass is held at the treating temperature. That these curves really represent processes going on inside the glass and are not due merely to peculiarities in the measuring apparatus is shown by a comparison of the changes in conductivity and measured changes in density for one of the glasses. The changes in conductivity in each instance occur at the same times of heat treatment as the corresponding change in density. It is also to be noted that the conductivity is a more sensitive indicator of the progress of the phase separation than the density, since a $^1/_2\%$ change in density is found to correspond to a 100% change in conductivity.

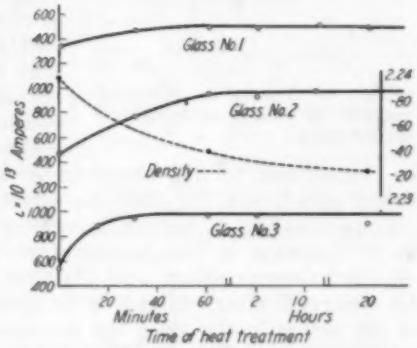

FIG. 7.—Anomalous charging current as affected by heat treatment.

(1) Chilled *vs.* Annealed Glass In continuance of the study of the dependence of electrical conductivity at room temperature on thermal history, a series of measurements was made on a chilled and annealed glass. In Fig. 8 the charging current curves are shown for a borosilicate-opal glass in the chilled state (above) and in the annealed condition (below). The conductivity at room temperature was found to decrease by no less than a factor of four in changing from a chilled to an annealed state.

(2) Mechanical Strains Not a Factor The discovery of this remarkable change in conductivity by chilling raised the interesting question as to whether or not the observed electrical change was due to the mechanical strain produced by the chilling. In Fig. 9 two forms of sample are shown which were used in experiments on the effect of strain produced by mechanical stress on electrical conductivity. At the top a flat plate sample is shown provided with tin foil electrodes and mounted on knife edges. The central inverted knife edge which supported the load was so formed that it made contact with the sample only on the upper electrode. Conductivity measurements with the pliotron showed no variation whatever when the loads were added and removed, the weight being increased until the breaking point of the glass had been reached.

To guard against the possibility of the effect of compression produced in the upper layers of the sample by the cross-bending forces being in some way compensated or balanced out by the effect of extension in the lower layers, a second form of sample was prepared for further tests, as shown in the lower part of the figure. A solid ball of glass about $^1/_2$ inch in diameter was worked up in the middle of a thick walled glass tube, and tungsten rods were sealed into the ball to serve as electrodes. The remaining arms of the tube served to eliminate surface leakage. Compressive force could be applied through an insulated screw press on which the sample was mounted. This sample, when compressed, showed a sudden 3% increase in electrical conductivity which remained and died out slowly after the pressure was released. No other change was observed. Since the changes in electrical conductivity previously observed in the chilled glass were of the order of 400% in comparison to 3% observed in the mechanically compressed sample, it was concluded (1) that the effect of the sudden mechanical strain is thermodynamic in nature increasing the electrical conductivity by the slight increase in the temperature of the glass ball brought about by adiabatic compression, and (2) that the large increase in conductivity to be observed after chilling is independent of the strain in the glass but is caused by "freezing" in some structure of the glass representing an equilibrium configuration or state of the molecules at a higher temperature with a consequent carrying down and preservation of this state at ordinary room temperatures. At present this work is being continued on a series of chilled glass samples of such form that the degree of chilling can be measured optically with polarized light and studied in relation to the electrical behavior of the sample.

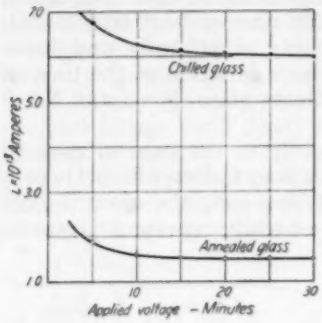

FIG. 8.—Anomalous charging current in chilled and in annealed glass.

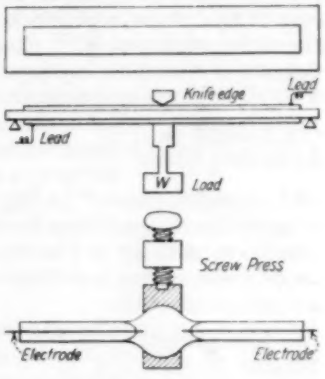

FIG. 9.—Samples used in mechanical strain-electrical conductivity tests.

VIII. Effect of Intense Radio Waves Passing through Glass on Its Electrical Conductivity

Because of its dual nature at low temperatures, it was thought that glass, which behaves as an excellent dielectric freely transmitting alternating electric fields as in a condenser and which, at the same time, behaves as an electrolytic conductor transmitting electric currents by means of moving ions, might possibly show some form of interaction between these two different aspects of its electrical nature. Accordingly, several attempts were made to measure the direct-current conductivity of glass with and

without a radio frequency field superposed on the direct-current field applied to the sample.

As was to be expected, great difficulty was encountered in finding a way to pass an appreciable radio-frequency current through the glass sample without at the same time upsetting the operation of the pliotron, thereby making it impossible to measure the very minute direct current, many thousands times smaller than the alternating current due to the high frequency field.

The final circuit developed for this purpose is shown in Fig. 10. The radio-frequency oscillator at the left is coupled through two condensers, c and c', to the glass sample which is in series with a variable air condenser, c'', that can be adjusted to the same capacity as the sample itself. The condensers, c and c', thus serve to transmit radio-frequency current measured by the milliammeter, M, through the sample and at the same time they insulate the sample from the oscillator so that the minute direct current due to conduction is not lost on its way to the control grid of the pliotron. The condenser, c', connected to the pliotron is of special design and construction to preserve almost perfect insulation. The two resistors of 10^6 and 10^8 ohms, respectively, damp out the high-frequency current and prevent it from going directly into the pliotron. The fact that the variable condenser, c'', can be adjusted to match the capacity of the sample also helps to minimize the radio-frequency current which escapes into the direct-current measuring circuit.

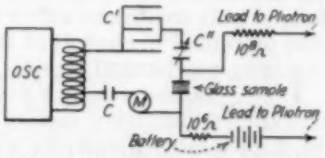

FIG. 10.—Circuit for sending radio waves through glass sample during measurement of electrical resistance.

Many attempts were made to find the effect of the radio-frequency fields on the direct-current conduction current by using the above circuit with several different kinds of glass. The superposed fields were of sufficient intensity to produce radio-frequency currents through the glass sample ranging from 55 to 120 milliamperes. An apparent 15% decrease in direct-current conductivity was found in certain of the tests when the radio-frequency field was applied. The same change in the pliotron reading was observed, however, when a dummy sample consisting of an air capacitance shunted by a resistance (each of the same order as the corresponding property of the glass) was substituted for the sample.

The conclusion finally reached is that no measurable change was produced in the direct-current conductivity of the glass by the applied radio-frequency fields under the conditions of the tests. Such apparent changes as were found in certain cases are attributed to the effect of the applied radio-frequency fields on the pliotron and associated measuring equipment rather than in the glass itself. At present somewhat similar experiments are in progress in which the converse effect is being looked for, namely, the effect of direct-current dielectric polarization on the power factor of the glass at radio frequency.

IX. Conclusions

By way of conclusion the foregoing discussion may be summarized briefly as follows:

(1) Glass at room temperatures, in addition to being an excellent dielectric, is a conductor of electricity, its resistivity ranging anywhere from 10^8 to 10^{16} ohms.

(2) The technique and accuracy of conductivity measurements on materials with this order of resistivity have been greatly improved and facilitated by the development of the pliotron vacuum tube for this type of work.

(3) Measurements with the pliotron show that the time required for the current flowing in the glass to reach a final steady state may vary from a few minutes or less on high conductivity glasses a little above ordinary room temperatures up to several hours in low conductivity glasses at low temperatures.

(4) Experiments at Corning have shown that just as the electrical history of the glass at low temperatures determines its subsequent behavior, so also does the thermal history as indicated by the pronounced variations produced by chilling and the changes brought about by prolonged heat treatment above the annealing point. Further, more evidence was presented to show that the effects of chilling are not due merely to the resulting mechanical strain.

(5) A radio-frequency field applied to a sample of glass during direct-current conductivity measurements produced no effect which could not be duplicated without the glass in the circuit.

Finally, it is desired to express the conviction that the study of the electrical behavior of glass at room temperature is of importance not only because of its direct application to the practical problems of supplying the electrical industries and laboratories with better insulators but also because of contributions of scientific interest to dielectric theory. Such study should provide more information concerning the fundamental nature of glass, especially since certain of the electrical properties seem to be sensitive indicators of changes in structure and thus to constitute a new and useful tool for obtaining indirect information on certain characteristics of glass not usually thought of in this connection. It is desired, however, to emphasize the fact that the experiments described are largely of an exploratory nature and more complete work is in progress.

CORNING GLASS WORKS
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VISCOSITY-TIME-TEMPERATURE RELATIONS IN GLASS AT ANNEALING TEMPERATURES*

By Howard R. Lillie

ABSTRACT

Viscosity data published by the author in 1931 are discussed with reference to their limitations. New experiments on fiber elongation in a redesigned apparatus are described in which one of the glasses previously used is tested. The results show that the viscosity of a newly drawn fiber increases with time of heat treatment according to a definite law which may be explained on the basis of a change in the state of aggregation in the glass. A finite equilibrium viscosity is indicated at each temperature, this limit being approachable from either side depending on previous heat treatment of the sample. This is taken to indicate an equilibrium average size of aggregate for any temperature, the groups starting to break up again if the temperature is increased after a long treatment. The expression of Sheppard and Houck is used for estimating effective molecular or aggregate weights in equilibrium at various temperatures, an example being 112,000 at about 500°C. The variation of viscosity with time is at least one reason why glasses fail to conform to Adams' and Williamson's annealing equation at low temperatures.

I. Introduction

In a previous paper[1] viscosity data between the lower limit of the annealing range and about 1400°C were reported for three special pure soda-lime silicates. The usual rotating cylinder method was used at the higher temperatures while fiber elongation was employed in extending the observations to temperatures below the "softening point" (about 680°C for these glasses).

The curves obtained by the two methods joined at the softening point with no discontinuity in actual magnitude but showed a rapid increase in slope between 700° and about 600°, at which temperature the log η *vs.* temperature relation became essentially linear. This linear part of the relation extended through the ordinary annealing range.

It has been found that this method can be used to good advantage in finding the temperatures limiting the annealing range for any glass, these limits being termed the "annealing point" at which the $\log_{10}$ of viscosity is 13.40 and the "strain point" at which it is 14.60. Annealing schedules made up from no other experimental data than these two temperatures will invariably give good commercial annealing in ware of ordinary size.

The purpose of the work reported in 1931 was to fill in the viscosity curve between the annealing and softening points and to show that real viscosities in ordinary units could be computed directly from the fiber dimensions, load, rate of elongation, etc. The experiments themselves were performed under changing temperature conditions, while the fiber was not uniformly heated over its entire length. This necessitated the use of an empirical correction factor in order to reduce the measurements to absolute units, which factor depended largely on both temperature and temperature distribution, making its determination especially difficult at the higher temperatures.

Since the present experiments were designed primarily for a study of the effect of time on viscosity, it was essential to modify the procedure

* Presented in part at the Annual Meeting, American Ceramic Society, Pittsburgh, Pa., February, 1933 (Glass Division). Received July 13, 1933.

[1] H. R. Lillie, "Viscosity of Glass between the Strain Point and Melting Temperature," *Jour. Amer. Ceram. Soc.*, **14** [7], 502 (1931).

and to change the equipment so that a high degree of uniformity of temperature was attained over the entire length of the specimen of glass under measurement.

In addition to the usual difficulties in studying properties of materials at elevated temperatures, it has been noticed frequently in recent years that in glass these properties generally are not determined entirely by the instantaneous temperature. It was observed in Fig. 3 of the 1931 paper[1] (page 508) that the computed viscosities shift suddenly when the load is increased. This indicates either a true plastic state, in which the strain per unit stress increases as the stress increases, or an elastico-viscous reaction which before disappearing requires a length of time comparable with that required by the experiment itself. These two explanations of the observed effect can be experimentally differentiated only by holding at constant temperature for long periods with various loads imposed. Any observed change with time might then be caused either by work hardening, as in certain metals, or by the heat treatment independently of the stress. In this event one should discover which of the two explanations is the true one.

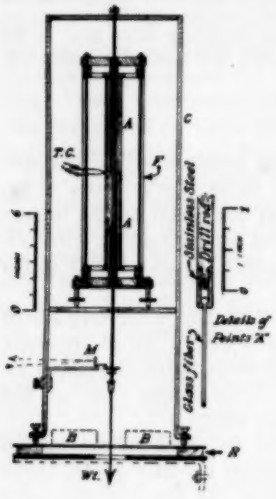

FIG. 1.—Apparatus.

With these considerations in mind the work has been continued with a few changes in technique to alter its object effectively from that of observing the change of viscosity with temperature alone to that of studying the relations between viscosity and time at different temperatures and under various loading conditions.

II. New Apparatus

Figure 1 represents diagrammatically the new apparatus used in the recent experiments. The following are the principal changes made since the previous report.

The furnace is built in about the same way except that (1) the core is of copper, wound noninductively with nichrome wire with the turns somewhat closer at the ends than at the center; (2) a control thermocouple, *T.C.*, is placed very near the winding at the middle of the core; (3) eight measuring thermocouples are inserted into small holes drilled into the core parallel to its axis to various depths so that the temperature over the whole length of the sample can be measured.

The furnace is supported by a brass ring carrying three leveling screws which rest upon the lower steel disk of a frame, *C*. This frame consists of three heavy upright steel bars fastened to two steel disks, the upper of which holds the sample suspension system and the lower supporting the furnace as mentioned. The legs of the frame are fitted with leveling screws. The whole rests upon an annular steel disk weighted down with three large masses, *B*. Between the annular disk and the supporting steel shelf are three large pieces of sponge rubber, *R*.

The sample of glass, being a uniform fiber of about 0.90 millimeter in

diameter and some 15 centimeters in length, is fastened between two steel rods as indicated in the small sketch at the right of Fig. 1. Weights, *Wt*, are applied as shown and elongations are measured by means of the small optical lever carrying a mirror, *M*.

III. Temperature Control and Distribution

The temperature of the furnace is controlled by means of the chromel-alumel couple, *TC*, and a Leeds and Northrup "micromax" controller. With the control couple close to the windings it was found best to make and break the whole furnace current, thus causing the fluctuations in temperature at the couple to take place several times every minute. Due to the high potential characteristics of the chromel-alumel couple the control instrument maintains a constancy of about $\pm 1°C$ and, with this variation taking place as fast as it does, no measurable periodic fluctuation can be observed in the temperature of the measuring couples (*i.e.*, $\pm < 0.05°C$). Due to the automatic features of the new "micromax," variations in the average temperature of the specimen over long periods seldom exceed $\pm 0.3°C$.

The variation of temperature along the length of the sample is generally about $\pm 1.5°C$. However, by means of the eight measuring couples the mean effective temperature of the sample can be computed quite accurately.

IV. Temperature Measurement

The thermocouples inserted into the holes in the furnace core are chromel-alumel, the cold junctions being maintained at 0°C. The electromotive forces are observed by means of a Leeds and Northrup type K potentiometer certainly correct to 0.002 millivolt, which is about 0.05°C in this case. The stock of wire from which the couples were taken was calibrated by the Bureau of Standards and guaranteed to $\pm 3°C$. It is assumed, however, that the accuracy of the calibration is much better than the stated guarantee indicates.

V. Glass Used

For the work to be reported here samples of the special glass I were used. These fibers were drawn from glass saved from experiments previously reported and so are of the same composition. To avoid any confusion, the analysis is repeated here:

SiO_2	Na_2O	CaO	K_2O	B_2O_3	Total
69.73	20.96	9.05	Trace	0.18	99.92

VI. Computation of Viscosity

In each experiment to be reported, the scale readings were first plotted against time, using the minute as a convenient unit. The slopes of this curve were then determined for different times. The following equation was then used:

$$\eta = \frac{60\,LmgF}{3\pi R^2 S}$$

Where L = fiber length in cm.
m = suspended mass in grams.

g = gravity constant.
F = multiplying factor of optical lever (248 in the present work).
R = fiber radius in cm.
S = slope mentioned above.

The factor 60 is to change time units. In cases where the fiber elongated considerably corrections were applied for the changes in L and R. Small corrections were also applied when necessary (very rare) to make all slopes correspond to a common temperature.

At higher temperatures the optical lever was not used, direct readings being made of the end of the steel rod against a scale using a telescope at some distance to eliminate appreciable parallax.

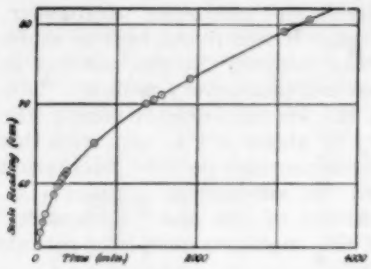

FIG. 2.—Elongation curve for 477.8°C.

VII. Experimental Results

Figure 2 shows the first elongation curve attempted at constant temperature, in this case 477.8°C. The total suspended mass was 1070 grams. As can be readily seen the elongation rate or slope, S, of the curve decreases in a regular way as time goes on, showing a decrease in the glass mobility. This curve is typical of those observed.

Figure 3 shows viscosities computed from the Fig. 2 curve plotted as points in squares. The viscosity is seen to increase by a factor of 10 during the first 60 hours.

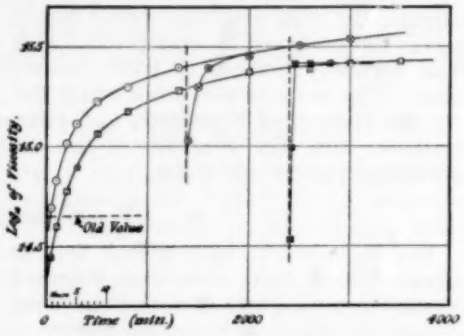

FIG. 3.—Viscosity-time curves for 477.8°C.

As mentioned in the introduction this decreased mobility might be due to either of two causes, (1) a change in the glass accompanying treatment at this low temperature, or (2) a like change caused by the work done in stretching. Of course these can be differentiated either by observing the effects of different weights, which in addition will serve to test the glass for plasticity, or by heat-treating a sample before testing and observing its behavior, since a heat treatment effect should proceed as well in the absence of the stretching force. These two kinds of tests were both applied at 477.8° with results included in Fig. 3. The points in circles were found with a suspended mass of 466 grams. The fact that all viscosities are higher than for the 1070-gram mass would seemingly point to a plastic condition. However, upon changing the weight to 1070 grams after 1380 minutes (marked by the dotted line) an elastico-viscous elongation is shown (crosses in circles) after which the viscosity-time curve forms a true continuation of the 466-gram part. It was therefore concluded that plasticity could not account for the curve being higher than the one first

observed. The first curve, however, is probably more nearly correct since it is supported by observations on the third sample of glass, to be described below. The uncertainty (25%) is equivalent to about 2°C change in temperature and would not be very significant on the complete viscosity curve (Fig. 9).

The crosses in squares are points observed for a third sample which had been previously heat-treated at this same temperature for 2400 minutes, during which time only the steel rod (about 30 grams) was hanging from it. The weight was increased at this time to 1070 grams. There was a rapid elastic elongation which lasted at a decreasing rate for about an hour at the end of which time the viscosity became essentially constant as shown. This was followed by a further small increase by the next day. Moreover, the values agreed with those attained in the first sample after equal total times, thus showing beyond doubt that the viscosity increase is a real change of property which takes place spontaneously in the glass during heat treatment and not a work-hardening effect as observed in some metals such as annealed copper at room temperature. Further, it may be said with fair certainty that at any given time, at least at this temperature, the glass is purely viscous but might not seem so in actual test unless time is given for elastic reactions to work themselves out. This same thing may perhaps be said of all liquids, except that the lengths of time involved are usually very short due to low viscosity.

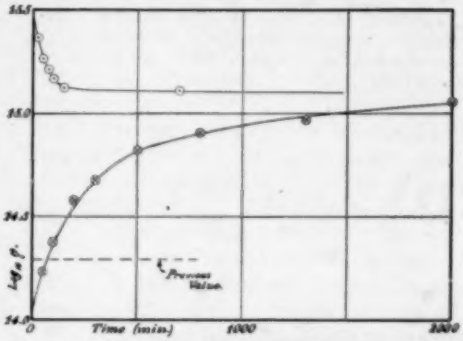

FIG. 4.—Viscosity-time curves for two samples at 486.7°C. The upper curve is for a sample previously treated at 477.8° for 64 hours; the lower curve is for a newly drawn sample.

The next question is whether the viscosity continues to increase to relatively very large values or whether it simply approaches a level corresponding to a true equilibrium state in the glass. In the latter case it should be possible to approach this equilibrium from the two sides. For instance, the increase in viscosity may be pictured as a slow building up of aggregates until the tendency to continue building up is held in equilibrium with the kinetic forces tending to destroy the groupings. If, after approaching quite nearly this final aggregation condition at one temperature, the sample is then heated to a higher temperature the aggregates will start breaking up and the viscosity will slowly decrease with time toward a new equilibrium state. However, if temperature simply regulates the rate at which the glass approached a state having infinite viscosity instead of dictating a final finite value to be approached, then an increase in temperature can cause only a temporary decrease in viscosity, this property again assuming its upward trend after temperature uniformity has been established.

Upon trial the glass was found to conform with the first hypothesis outlined. This is shown in Fig. 4 where the plain points show the de-

crease in viscosity of the third sample when, after about 64 hours at 477.8°, it was suddenly raised to 486.7° without disturbing its load. As will be seen the viscosity decreased quite rapidly at first and then more slowly. Three hours were required for the rapid descent to the end while temperature uniformity was certainly established in one-tenth of this time. The graph does not show positively that the viscosity continued to decrease as long as the run was extended but this is apparent in the original data. The other curve on the Fig. 4 graph is for a new fiber at the same temperature. Figure 5 shows how the equilibrium viscosity has been determined by replotting these two curves against the reciprocal of time. The graph does not leave much doubt as to the equilibrium viscosity condition at this temperature.

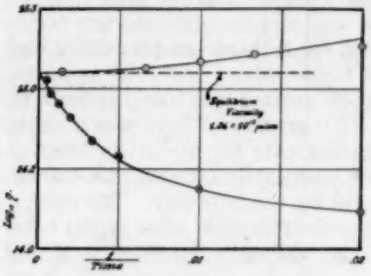

FIG. 5.—Data from Fig. 4 plotted against the reciprocal of time to show convergence to common value at infinite time.

Figures 6 to 8 show similar effects at various temperatures in small steps up to 520.2°C. A few observations can be made from these figures as follows: (1) As temperature increases the glass is originally nearer to its final state; and (2) the distance it has to go to reach equilibrium is covered more and more rapidly. The upper part of Fig. 8 has an extra curve marked by circles with single lines through them. This run differed from the other in having 238 grams suspended instead of 1070. The way the two curves approach each other at long times indicates that the divergence at the start was caused either by the zero times not corresponding exactly or by a difference in the degree of chilling the samples had undergone on being drawn. If any plasticity is present in the glass it can not be detected.

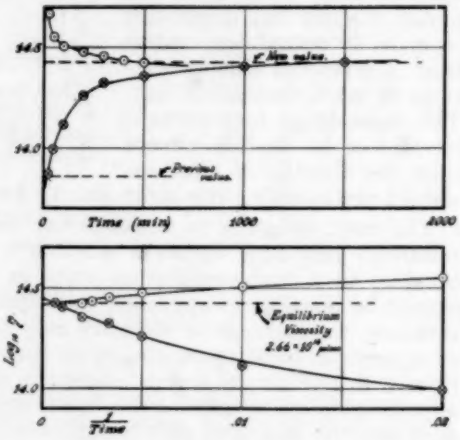

FIG. 6.—Results for 497.6°C.

Further runs were made at temperatures above those covered by the graphs. In these cases, however, equilibrium is apparently established so quickly that the viscosity seems to be a perfectly constant value which can be determined in a very short time.

One additional run was also made at 465° on a sample which had been previously heat-treated at this temperature in a different furnace and under no tension at all for about 170 hours. At the end of this time it was transferred to the testing furnace and viscosities were determined during four more days. The logarithm value started at about 15.49 and results

indicated a value of 16.12 at infinite time. This same fiber was then heated to 474.8°C and after two days the viscosity was still gradually decreasing, apparently toward 15.75 as a limit.

VIII. Results Tabulated

The following table gives a résumé of the new results as well as a comparison with those of the 1931 paper:

TABLE I

°C	Log η_∞	Log η_0	1931 value	Time for η to be 1931 value
465.0	16.12		15.15	
474.8	15.75		14.77	
477.8	15.53	14.35	14.65	130 min.
486.7	15.10	14.05	14.29	70
497.6	14.42	13.73	13.86	20
505.5	13.92	13.35	13.54	23
509.4	13.65	13.32	13.38	9
520.2	12.98	12.75	12.95	30 (?)
540.8	11.93		12.15	ΔT = 6°*
560.5	11.09		11.38	7
581.1	10.21	Equilibrium	10.56	9
610.5 (40 gm.)	9.23	established	9.46	6
615.3 (3.3 gm.)	9.08	very quickly	9.29	6
636.8 (3.3 gm.)	8.48		8.60	4

* Temperature difference corresponding to difference between 1931 values and present ones.

It will be noted that η_0 compares with the 1931 results in such a way as to indicate that the latter were correct for short heat treatments.

Attention may be drawn in passing to some work published by the author a year ago,[2] consisting of an attempt at precise measurements of viscosities near the annealing point by means of interference observations made on samples under pressure. This work has not been taken up again but appears now to have more promise than before. The values obtained at that time were higher than were expected but it is clear now that this should have been the case since extended heatings were a necessary part of the experiments. According to the new results the equilibrium viscosity at the annealing point is about 4.7 times 10^{13} poises, while the results found by the totally different method for the crown and flint glasses were 7.4 and 4.5 times 10^{13}, respectively.

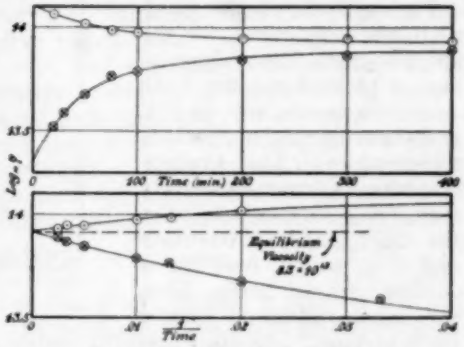

FIG. 7.—Results for 505.5°C.

[2] H. R. Lillie, "Precise Measurements of the Viscosities of Glasses at Temperatures Near Their Annealing Points," *Jour. Amer. Ceram. Soc.*, **15** [8], 418 (1932).

IX. Consideration of Association in the Glass

Relationships between temperature and liquid viscosities have been studied in some detail by Andrade and others.[3] Many equations have been developed to fit the data for a limited number of liquids in limited temperature ranges but apparently the one having the best theoretical basis is

$$\text{Log } \eta = K_1/T - A$$

where T is absolute temperature, and K_1 and A are independent of temperature as such.

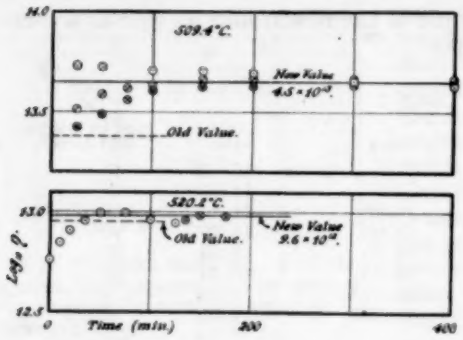

FIG. 8.—Results for 509.4 and 520.2 °C.

Preston[4] points out that this equation has been used empirically for some time, as well as other relations from which it may be derived. He also notes that it may be found by simple analogy to the Boltzmann vapor pressure expression.

Sheppard and Houck[5] have also derived the same equation by a consideration of molecular orientation probability and point out that it should hold true for simple liquids, either nonassociated or of a constant degree of association over any temperature range. They further cite linear relations between log $1/\eta$ and $1/T$ for a variety of liquids.

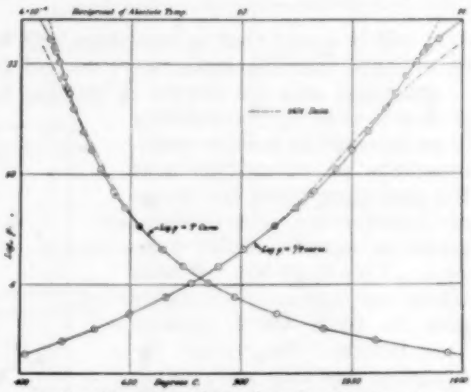

FIG. 9.—New complete viscosity-temperature curves for L1 glass.

Figure 9 shows the complete viscosity curves for the special glass, the values of $\log_{10} \eta$ plotted against both actual temperature in °C and the reciprocal of absolute temperature. The broken-line curve is drawn accurately from the results tabulated in the 1931 paper. Attention may be drawn here to a similar graph made from the same tabulated results by Waterton.[6] In discussing the earlier measurements, he concluded that

[3] (*a*) E. N. da C. Andrade, "The Viscosity of Liquids," *Nature*, **125**, 309 (1930); (*b*) S. E. Sheppard, "The Relation of Fluidity of Liquids to Temperature," *ibid.*, **125**, pp. 491 and 709 (1930); (*c*) Andrade and others, "The Viscosity of Liquids," *ibid.*, **125**, 580 (1930).

[4] F. W. Preston, "The Temperature Coefficient of Viscosity and Its Relation to Some Other Properties of Liquids and Glasses," *Jour. Amer. Ceram. Soc.*, **15** [7], 365 (1932).

[5] S. E. Sheppard and R. C. Houck, "The Fluidity of Liquids," *Jour. Rheology*, **1** [4], 349 (1930).

[6] S. C. Waterton, "The Viscosity-Temperature Relationship and Some Inferences on the Nature of Molten and of Plastic Glass," *Jour. Soc. Glass Tech.* (Trans.), **16**, 244 (1932).

a constant state of aggregation sets in as the temperature is lowered past the softening point. He based this conclusion upon the fact that there was at this point a noticeable change in the form of the curve. However, as will be seen in Fig. 9, the recent more accurate results show that the change noted by Waterton does not exist. The curve is now quite smooth over its whole length until a temperature somewhat below 500°C is reached. At this point a change in the form of the curve takes place, indicated by the last four points. There is every reason for assuming that these points represent equilibrium values; the change in the curve, then, may perhaps mean a sort of transformation. It occurs, however, appreciably below the annealing point and at a viscosity of about 10^{15} poises and so does not correspond in any way to transformation points that others claim to have observed.

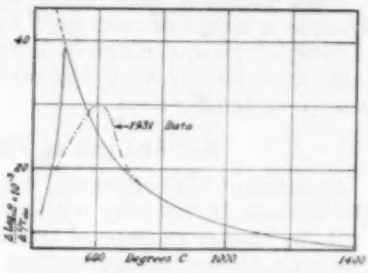

FIG. 10.—Slopes of $\log_{10} \eta$ *vs.* $1/T$ curve plotted against temperature.

As has been generally noticed for glasses, the $\log_{10} \eta$ *vs.* $1/T$ relation is not linear.

Sheppard also derives an expression making K_1 proportional to $c(M\rho)^{2/3}$, where c is the specific heat, M the molecular weight, and ρ the density, and finds that the constant of proportionality is essentially the same for all "normal" liquids so that

$$\frac{c(M\rho)^{2/3}}{K_1} = 0.0213^*$$

By the use of this expression, with the specific heat and density known, the effective molecular weight may be computed from the slope of the $\log_{10} \eta$ *vs.* $1/T$ curve. If the curve is not linear (as the ones given by Sheppard for water, acetic acid, etc., and, similarly, ours for glass I), it may be supposed to signify a change in degree of association or aggregation with temperature and, at least hypothetically, the effective molecular weight may be found for any temperature by measuring the slope at that point and computing accordingly. This has been done by Sheppard and Houck for several liquids with apparently reasonable results.

It will be interesting to apply this analysis to the viscosity-temperature relation for the glass under examination. The slopes, $K_1 \left(= \frac{\Delta \log_{10} \eta}{\Delta 1/T \text{ abs.}} \right)$, have been determined from the full line graph in Fig. 9 and are plotted against temperature in Fig. 10. The position of the curve as required by the 1931 data is given by the broken line marked as such, while the full line represents the present results. It is felt that if true equilibrium were attained the values of the slope should continue on the upper dotted line, although the sudden decrease below about 500°C is unmistakably indicated by the results as observed.

The following estimates on the basis of Sheppard's equation have been made for the effective molecular weight of the glass:

* Given as 21.3 by Sheppard, either through error or a change of units.

Slope	M
10,000	15,000 (about 1100°C)
20,000	42,000
30,000	74,000
40,000	112,000 (about 500°C)

The largest of these would correspond to an average aggregate of effective diameter 5 times 10^{-7} centimeters.

These values of molecular or aggregate weight may be far from correct, since, in a liquid of such high viscosity and composed of such a variety of complex groups, different laws may govern the rate of increase of viscosity with temperature than are applicable to simple low-viscosity liquids near room temperature.

X. Analysis of Viscosity Increase with Time

An attempt has been made, with some success, to express by an equation the increase in viscosity with time.

If the change of slope of the log η *vs.* $1/T$ curve is considered as being due to a change in aggregation and the difference between the present results and the 1931 results as being caused by this aggregation not having time to take place fully in the older experiments, then it is natural to explain the time variation of viscosity on the basis of a slow building up of these same aggregates.

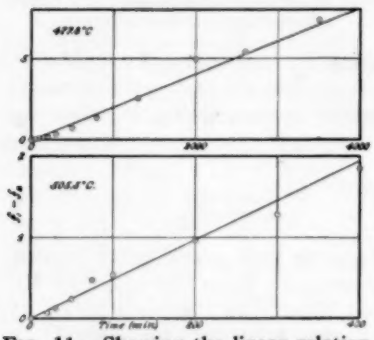

FIG. 11.—Showing the linear relation between $f_1 - f_2$ and time.

Since at infinite time there is a true equilibrium viscosity, the rate of change will finally become zero. Moreover, the building up of aggregates requires a certain amount of migration of the small units toward each other, which movement will be resisted by the viscosity itself. Now, although nothing is known about the relations between size of aggregate and viscosity itself or between mass viscosity and the viscosity which affects motions of particles of molecular dimensions (*i.e.*, whether these relations are linear), the expression should be of the general form

$$\frac{d\eta}{dt} = \frac{K_2(\eta_\infty - \eta)^A}{\eta^B}$$

where t is time and η_∞ is the equilibrium value for viscosity. As was hoped, it was found that A and B could both be taken as unity.

For the purpose of testing the viscosity variations this equation was put in the form:

$$2.30 \log_{10}\left(\frac{\eta_\infty - \eta_0}{\eta_\infty - \eta}\right) - \frac{\eta - \eta_0}{\eta_\infty} = \frac{K_2}{\eta_\infty} t$$

or

$$f_1 - f_2 = \frac{K_2}{\eta_\infty} t$$

These functions have been computed from the results for all the temperatures from 477.8 to 509.4, inclusive. Table II shows two sets of such computations while Fig. 11 shows how linear the $(f_1 - f_2)$ *vs.* time relation is.

TABLE II

Temperature (°C)	Time (min.)	η	f_1	f_2	$f_1 - f_2$
477.8	0	2.24×10^{14}	0	0	0
	50	2.76	0.018	0.015	0.003
	100	3.96	.060	.051	.009
	200	5.97	.129	.110	.019
	300	7.9	.200	.169	.031
	500	11.6	.352	.278	.074
	800	14.9	.513	.376	.137
	1300	18.9	.750	.494	.256
	2000	23.6	1.130	.633	.497
	2600	24.2	1.190	.651	.539
	3500	26.4	1.452	.716	.736
	∞	33.8			$K_2 = 6.9 \times 10^{11}$
505.5	0	2.2×10^{13}	0	0	0
	20	3.3	0.198	0.133	0.065
	30	3.9	.327	.205	.122
	50	4.8	.55	.31	.24
	75	5.8	.90	.43	.47
	100	6.1	1.01	.47	.54
	200	7.0	1.54	.58	.96
	300	7.4	1.91	.63	1.28
	400	7.8	2.51	.67	1.84
	∞	8.3			$K_2 = 4.0 \times 10^{11}$

The following values of K_2 were determined at the various temperatures:

Temperature (°C)	K_2
477.8	6.9×10^{11}
486.7	5.6
497.6	5.7
505.5	4.0
509.4	4.4

It was observed further that the constant K_2 is apt to vary considerably from sample to sample at the same temperature and apparently depends to some extent on the previous chilling of the sample. This probably accounts for the trend in K_2 not being very regular. Figure 12 shows the values plotted against temperature. K_2 does not seem to be quite independent of temperature but decreases somewhat as the temperature is raised. It differs in this way from ordinary reaction rate constants but this difference is not surprising when it is considered that we are dealing with the rate of change of a physical property whose dependence upon molecular conditions is not known in any detail.

XI. Application to Annealing

As was stated in the introduction, annealing and strain points determined in the old way, as described in 1931, have been found to be sufficient for making up an effective annealing schedule for ordinary ware. This is because the usual cooling rates are fast enough so that appreciable time changes in viscosity can not take place and the glass comes down to

room temperatures with an internal arrangement corresponding to the equilibrium near the annealing point itself. In other words with the relatively rapid cooling possible in small ware a material of practically constant structure is being used.

However, in annealing large sections of glass the cooling rate is very slow and the viscosity-temperature relation will not be the same as before. The annealing point will not be changed much but the strain point might be raised considerably (15° in glass I). This would have the effect of shortening the time required in the cooling process, giving a real advantage if the article requires several weeks to pass this critical temperature range. In order, then, to determine the minimum annealing and cooling time one should take this additional change of viscosity into account.

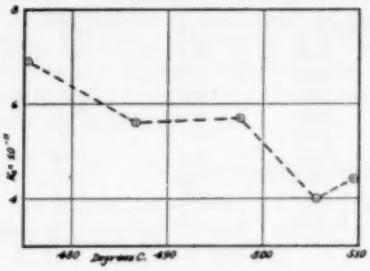

FIG. 12.—Showing dependence of K_2 upon temperature.

The information at hand is still insufficient for making up an annealing schedule taking account of this additional variation but there is certainly a possibility of this being done in the future.

Another interesting deduction which can be drawn from the viscosity-time-temperature relations has to do with the laws of annealing as formulated by Adams and Williamson[7] and later discussed dimensionally by Preston.[8] It will be remembered that Adams and Williamson gave, for the rate of release of stress, the expression

$$-\frac{df}{dt} = Af^2$$

or

$$1/f - 1/f_0 = At$$

where f is the stress, expressed as birefringence, and A, the annealing constant, a function of temperature only.

Preston, in explaining the formula from the standpoint of dimensional analysis, substitutes B/η for A, making B a dimensionless constant and η a function of temperature alone.

It will also be remembered that at temperatures somewhat below the annealing range, Adams and Williamson found that the $1/f$ *vs.* time curve failed to be linear, its slope A decreasing as time went on. This variation in A (likewise B/η) can now be qualitatively explained by the increase in η with time. By further investigation of these relations, the writer hopes to be able later to state a complete annealing law in which the viscosity, as a function of both temperature and time, will serve to eliminate the time variation of the constant, B.

XII. Conclusions

The conclusion is drawn that the viscosity of a glass is not a function of temperature alone but depends upon previous heat history even when

[7] Adams and Williamson, "The Annealing of Glass," *Jour. Franklin Inst.*, **190**, 597 (1920).

[8] F. W. Preston, "The Fundamental Law of Annealing," *Opt. Soc. Trans.* [London], **26**, 270 (1924–25).

there is no indication of crystallization or plasticity. There is a finite equilibrium value of viscosity which this property approaches, the rate of approach being approximately proportional to the distance it still has to go to reach its final value and proportional also to the instantaneous fluidity. In this way, a reaction rate type of law is followed except that the constant involved seems to decrease with temperature rise. At temperatures above what is thought of as the annealing range, the attainment of equilibrium becomes too fast to be observed. The whole effect is pictured as being one of aggregate building which requires time to accomplish. By the use of the equation of Sheppard and Houck estimates of molecular weight may be made and these indicate an eight-fold increase between melting and annealing temperatures. The equilibrium molecular weight would perhaps continue to increase still faster below the annealing range if such heat treatment were given as to allow it, but the observations fail to show this definitely.

It is also tentatively concluded that the viscosity-time-temperature dependence is the reason for the failure of stresses in glass to be released at constant temperature in strict accordance with the Adams and Williamson law.

No indication of a plastic or true solid state was found although viscosities of more than 10^{16} were measured.

AUTHOR'S NOTE: The author regrets that he failed to mention in this paper work done by V. H. Stott several years ago. At that time Stott measured low-temperature viscosities and observed that time must be allowed for glass conditions to become steady. References to this work are as follows: *Proc. Roy. Soc.*, **A108**, 154 (1925); *Jour. Soc. Glass Tech.*, **9**, 207 (1925).

CORNING GLASS WORKS
CORNING, NEW YORK

NOTE ON THE DISCOVERY OF A KAOLIN DEPOSIT IN NEW MEXICO

By L. M. Richard

There has recently been discovered in New Mexico a deposit of the English type of kaolin which is of more than ordinary interest. These beds are located in Township 21 South, Range 3 East, Dona Ana County, and occur about fifty miles north of El Paso, Texas.

The deposits are of the residual type and have been formed through the chemical process of decomposition of feldspathic materials and leaching. They do not outcrop naturally but occur in the upper workings of a mine at one time worked for metalliferous minerals. The present estimated depth is from 150 to 200 feet from the surface.

The kaolin is massive and white in color. Tunnels of great length have been driven through it and it stands in remarkable fashion. For the most part the kaolin appears to have been formed similarly to the deposits in England. It is imminently plastic and fine in grain and due to its extreme whiteness is suitable for paper filler.

Tests which have been made show it to have admirable working qualities, comparable with the imported English variety.

Physical Tests

Color (wet)	White, opaque, pearly
Color (raw)	White, smooth to touch
Foreign materials	Few undecomposed feldspar grains Few splotches of carbon Little free angular silica
Drying shrinkage	8%
Slaking properties	Good
Specific gravity	2.72
Hardness	2.50
Luster when rubbed (dry)	Satiny
Macroscopic structure	Devoid of definite structure
Porosity	Absorbs water with avidity, porous
Absorption	Same as English washed kaolin
Fracture	Has no definite cleavage; on some samples shows flat breaking planes
Uses	Fine chinaware Refractory ware Paper filler
Development of mullite on firing	Small

Chemical Analysis

SiO_2	47.23	48.25	46.25	45.20
Al_2O_3	36.85	32.40	37.55	33.60
Fe_2O_3	0.42	2.36	2.00	2.24
CaO	0.06	0.41		0.06
MgO	Tr.	Tr.		Tr.
Na_2O	1.59	3.30	0.24	2.35
K_2O				0.25
TiO_2				0.01
SO_3	0.65			
H_2O	12.80	12.28	13.86	13.00
MnO	0.10			0.09
	99.70	99.00	99.90	96.80
Firing shrinkage	$12^1/_2$%	P.C.E. 33 P.C.E. 32	Color at cone 30, gray	

This kaolin is suitable for the manufacture of all whiteware bodies. Owing to its plasticity it would need practically no addition of ball clay.

When fired with samples of English washed clay practically no difference could be noticed.

The kaolin would be suitable for the manufacture of refractory brick either alone or combined with purer varieties of fire clay.

The discovery of a deposit of the chemical purity as represented by this kaolin in the southwest is of particular interest inasmuch as this territory depends largely on outside sources for its ceramic products.

ROUTE 2, BOX 619
ESCONDIDO, CALIFORNIA

WATER-TIGHT TERRA COTTA MASONRY*

By F. O. Anderegg

ABSTRACT

In spite of the lessened opportunity for moisture to pass the face of a terra cotta wall as compared with brick masonry, certain precautions should be observed to produce a water-tight wall, especially where the exposure is severe. The bearing of each of the important properties of masonry cements in regard to their application to terra cotta is pointed out and recommendations are made for suitable cementing materials. Suggestions are offered for the selection of sand and for securing uniformity and intimacy of mix. A joint width of $^3/_{16}$ to $^1/_4$ inch is recommended where the regularity of the units permits. The joints should be shoved and given a tool finish at the proper stage of stiffening. The joints subjected to extra severe exposure should be packed with prehydrated mortar and properly tool-finished. Mortar may be aided to adhere to a glazed surface either by using prehydrated mortars or by first painting the surfaces with cement paint. For back-up, a hollow tile with webs vertical is recommended.

I. Introduction

Where terra cotta masonry is exposed to the weather, as in skyscrapers along the Atlantic coast, the careful architect and conscientious builder should take every precaution to secure a wall as nearly 100% tight as is economically feasible.

The amount of moisture passing through the terra cotta masonry unit itself, in view of the glazed surface, is negligible. The amount of moisture passing through the body of most mortars is small although, if porous, they may permit a slow dissemination of the salts resulting from contact with acid rain water; but they do not contribute more than a small portion of any leakage. Rain water enters the wall through incompletely filled joints or through openings between the units and the mortar, resulting from the use of insufficiently plastic mortars, from shrinkage while the mortar is still soft, or from both.

The large size of the terra cotta unit reduces considerably the part of the wall occupied by the mortar as compared with small units; in the same way the linear length of contact between the units and mortar is considerably diminished. Comparison of a unit, 12 by 24 inches set with quarter-inch joints, with standard brick laid in half-inch mortar, gives a mortar-area ratio of about 1 to 7 and a length-of-contact ratio of about 2 to 7.

While the opportunity for passage of moisture through the terra cotta wall is much reduced, it may not be neglected. Some of the salient points in the design and use of mortars which are being discussed may be expected to aid in securing a water-tight job.

If terra cotta masonry is used for facing on a building where movements occur, as they do in all large buildings, it is important that the wall have a certain flexibility to permit the movement to take place without serious effect on the integrity of the masonry. If the units should be bonded together with a strong cement mortar to form a monolithic wall, the result is often the development of cracks through mortar and units alike. The shortening of the steel frame as it takes up the load must be compensated in the outer wall by means of a suitable, compressible material placed at intervals.

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* Presented at the Annual Meeting, American Ceramic Society, Pittsburgh, Pa., February, 1933 (Terra Cotta Division). Received March 8, 1933.

II. Cementing Materials

Analysis of the properties important in masonry-cementing materials has been given elsewhere.[1] These will be discussed briefly here with particular reference to terra cotta.

(1) Plasticity The mortar must be quite plastic in order to secure complete contact with the units. It must have sufficient water-retaining power to allow spreading over the absorbent surfaces of terra cotta.

(2) Bond Strength The mortar should acquire a bond strength of at least 30 pounds per square inch in 28 days.

(3) Water-Tightness The mortar itself should permit the permeation of only small amounts of moisture so as to discourage any tendency toward the building up of a concentration of sea salts or of these salts formed by the action of sulfuric acid from rain water on the cementing materials. These salts, when present in sufficient amount, are active in promoting the disintegration of the mortar.

(4) Weather Resistance The mortar should stand up to the erosive and solvent action of rain water driven, at times, by high wind velocities. It should also be dense enough to resist the effects mentioned in paragraph (3).

(5) Flexibility The importance of this property was mentioned in the introduction. A section of terra cotta wall should show, when loaded in flexure to two-thirds of its breaking strength, a movement of about 0.001 inch per inch without breaking.

(6) Shrinkage and Shrinkage Rate All masonry mortars shrink as the moisture leaves them and as the setting and hardening reaction proceed. This is fundamental. The shrinkage in the horizontal joints, resulting from loss of moisture before the mortar stiffens, produces a network of capillaries between the mortar and the unit through which moisture passes. It is essential to design the cement so that this tendency is reduced to a minimum. The shrinkage, which continues for some time after the initial setting in the horizontal joints, is taken up by the weight of the wall and the only result may be the opening of a tiny crack just below the spandrel beam. This might be taken care of with an elastic joint, provided a satisfactory and durable material is available.

NOTE: This discussion does not apply to gypsum plaster mortars where the oriented growth of the gypsum crystal may result in an actual expansion during setting under certain conditions.

In the vertical joints, both types of shrinkage are apt to cause trouble, but both can be kept small by suitable designing of the cement. To avoid the second shrinkage, the cement must bond tightly with the unit and at the same time have sufficient flexibility within itself. The use of narrow joints is very important.

(7) Compressive Strength While this property as such may not be so important in a modern curtain wall, in view of the information as to the probable durability of the mortar obtained from the compressive strength, a minimum at 28 days of 1000 pounds per

[1] (*a*) F. O. Anderegg, "Construction of Water-Tight Brick Masonry," *Jour. Amer. Ceram. Soc.*, **13**, 315–24 (1930); *Arch. Rec.*, September, 1931.
(*b*) "Analysis of Properties Desired in Masonry Cements," *Rock Prod.*, **34** [25], 40–41 (1931).

square inch was obtained with specimens prepared under similar absorption and storage conditions as encountered by the mortar in the wall.

(8) Efflorescence Sufficient opportunity exists in most walls for soluble salts to be carried in without introducing them in the mortar. They have been found at times in the mixing water, in the sands, in the cementing materials, and even in some masonry units. Where possible, all masonry materials should be free from soluble salts. They often make their appearance soon after the erection of the wall, to the grief of all concerned.

(9) Setting Rate After the mortar is in the wall, it is usually desirable to have it set up and harden reasonably soon so that the work may be carried forward. If the mortar sets up before much moisture is lost, the formation of openings between units and mortar is controlled. The element of safety must also be considered.

In the choice or design of cementing materials, therefore, ingredients must be chosen which will contribute plasticity, such as limes and fine limestone, selectively hydrated natural cements, and true waterproofers. These same substances also provide flexibility and help to secure a sticky mortar.

On the other hand, materials should be added which contribute strength, faster setting, and higher durability, such as Portland cement or some of the natural cements.

To help control the important shrinkage property, the first requisite is to keep the water requirement of the cement as low as is consistent with good plasticity. Waterproofers, such as stearates, are helpful in this regard. Magnesia, found in dolomitic limes and in some natural cements, seems to have the property of lubricating the mix with the help of very little water; it also seems to have the ability to continue to hydrate slowly, with an expansion which more or less offsets that shrinkage accompanying the slow hardening reactions.

The cementing material recommended is one made from equal parts of lime putty, soaked at least ten days, and of Portland cement to which has been added (in such a manner as to produce a practically molecular dispersion) one-quarter pound stearic acid per bag of cement. Many of the masonry cements contain the equivalent of this mix, avoiding the necessity of soaking the lime. In some localities, central mixing plants furnish a well-aged putty with or without sand, suitable for making high quality mortar.[2]

III. Sand

Where choice of sand occurs, the selection should be one screened according to the joint thickness and, if possible, having all sizes present, ranging from quite fine to coarse. Too much sand in any one fraction is undesirable.[3] Loam or clay containing organic matter should be excluded.

IV. Mortar Mixing

It is important to secure a uniform and intimate mix. Where the size of the job permits, a mechanical mixer should be used. Most batch mixers

[2] EDITORIAL NOTE: Under no circumstances should a mortar be used for backing up terra cotta that is richer in cementing ingredients than one part by volume of cement, one of lime, and five parts by volume of sand.

[3] F. O. Anderegg, "Grading of Aggregate for Mortars," *Ind. Eng. Chem.*, **23**, 1058–64 (1931).

seem to give good results. Where the mortar is mixed by hand, unless the operator is quite skillful, he should be provided with some means more accurate than a shovel for measuring his sand. The point of thoroughness in mixing should be emphasized and for this a proper mechanical set-up is invaluable.

V. Workmanship

An important factor in getting satisfactory walls is the workmanship,[1] but the mason must be provided with appropriate materials and specifications before he can produce his best service.

(1) Joint Thickness Selection of the proper joint thickness is important in securing a water-tight wall. If the joints are too thick, it is necessary to provide a rather stiff, harsh-working mortar and very little pressure may be applied to the mortar, so that the contact is poor and leakage will probably occur. On the other hand, if the joints are excessively thin, the pounding required to place the unit in the allotted space often causes the mortar to slump out of the vertical joints leaving openings through which moisture readily passes. The ideal thickness, where the units are sufficiently uniform to permit, lies in the range of $^3/_{16}$ to $^1/_4$ inch.

(2) Shoved Joints The mortar is spread on the top of the lower unit in amount somewhat greater than is required to fill the joint. Mortar is also pasted on the vertical face of the unit being placed and it is then shoved into place to the specified joint thickness in such a way that contact is continuous and excess mortar is squeezed out. This detail should involve no increase in expense, provided the mason has been properly trained.

(3) Tool Finishing Joints Another extremely important detail is the proper finishing of the joints. Just as in finishing concrete floors, there is a proper time to work the mortar to get maximum packing, so it is with masonry joints. It is recommended to use a tool which will pack the mortar tightly into the joint and up against both masonry units. This operation is the final touch which has kept many a wall from leaking. Because of the lack of attention to this detail on the part of the mason, certain contractors prefer to rake out the joints while the mortar is still soft and assign one reliable man to the "pointing up" operation.

(4) Pointing Exposed Horizontal Joints When terra cotta is used for copings, projecting belt courses, window sills, etc., where the snow is apt to lie, special precautions are needed to secure a joint that will give satisfactory service. For such joints it is recommended to use a mortar containing equal parts by volume of lime putty[4] and Portland cement with four to five parts of sand, the mortar having been mixed one and one-half to two hours previously. It should then be reworked with the addition of very little water to produce a stiff putty which is then packed tightly into the joint. If the units are rather absorbent, they should be moistened with a wet cloth. Then, after the mortar has stiffened to the proper point, the mason should come back and finish with

[4] EDITORIAL NOTE: Experience on the West Coast has developed a preference against using lime for strictly pointing mortar, using fire clay instead in proportions of one part by volume Portland cement, two of clean sharp sand, and one-quarter part by volume of fire clay. Author: Such a mortar is also satisfactory.

a rounded tool, applying considerable pressure. This precaution should be taken also with vertical joints in projecting belt courses from which the mortar as usually applied is often forced out leaving a "weeping joint."

(5) Glazed Surfaces Where it is desired to make mortar adhere to glazed surfaces, two methods may be used. The one is to use prehydrated mortar as described in the preceding paragraph. The other is to apply a coating of Portland cement paint to the glazed surface. Mix a little neat Portland cement into a slurry of the consistency that will stick to the smooth surface and apply about two hours previous to use, where only a few units require the treatment. If many units need treating they should be painted in the factory, as soon as the initial set is reached, with a spray for forty-eight hours (the cement paint being cured).

VI. Masonry Back-Up for Terra Cotta Walls

Standard practice is to back up with common brick, slushing all openings as full as feasible. The speed attained in this operation is fair, although

FIG. 1.—A metal seepage bar may be used to divert moisture from penetrating joints in copings, cornices, and other exposed positions.

some time is lost clipping brick to fit in the openings of the terra cotta units. One disadvantage in this type of construction is the greater heat conductivity of the wall-slushed solid.[5] The lack of assurance of getting a water-tight back-up, should openings occur in the joints at the face, is based on numerous experiments with walls so built[5] and on observation on several large masonry jobs where the attempt to secure water-tight walls by conscientiously using plenty of mortar has signally failed. If opportunity is afforded to examine such slushed-in joints during the tearing down of the wall, it will be observed that numerous openings and passage-ways are left in the mortar, permitting ready passage of moisture.

Another objection is that a solid masonry back-up wall will get filled with moisture, provided openings occur in the face and, since the best mechanic is only human, some openings are quite certain to be left. Moisture gets into the wall and gradually builds up therein with increased heat conductivity and gradual disintegration of the mortar.

In view of these objections, it is suggested that a hollow tile back-up unit be designed and manufactured specifically for terra cotta walls. The webs should be vertical to provide drainage and ventilation within the

[5] *Arch. Rec.*, p. 210, September, 1931.

walls. A necessary corollary, of course, would be spandrel waterproofing; but this should be provided in any event. This suggestion is submitted with a full realization of the objections that will be raised, but it is respectfully offered in the firm belief that it would produce an improved terra cotta masonry wall.

(1) Parapet Walls What has been said about using an open structure back-up applies much more strongly to parapet walls where the exposure is more severe than in the main wall. It is strongly recommended to build all parapet walls of hollow units. A flashing could be extended through the wall just above the roof line to divert any moisture entering the wall out on to the roof through weep holes. Suitable provisions must be made to anchor the parapet wall against wind pressure.

(2) Copings A conservative estimate of the damage done by moisture penetrating copings is a million dollars a year. With terra cotta units the sealing of the coping joints is the important detail requiring attention. Two methods of securing water-tight joints are shown in Fig. 1. The presence of the beading there illustrated, extending parallel to the exposed faces, aids appreciably in obtaining a water-tight joint.

1829 Oliver Building
Pittsburgh, Pa.

TERRA COTTA CRACKING*

By Fred B. Ortman

I. Introduction

The purpose of this note is to convey a concise summary of the results of investigations made of the cause and prevention of a certain type of cracking which has occurred in the terra cotta on a few buildings in San Francisco, the most typical example of which is found probably in the Telephone Building.

II. Cause of Cracking

Conclusive results, after painstaking research on the part of our own engineers, supported and confirmed by separate investigations and conclusions by independent, capable, and unbiased investigators have shown definitely (1) that the cracking was due to the expansion under moisture of the mortar used in the brick backing with which the terra cotta was filled; and (2) that the expansion was destructive in the cases in question because of the unusual nature of the mortar formula used caused by (*a*) too rich in ratio of cementing ingredients to sand and (*b*) too high a percentage of a high magnesium hydrated lime.

III. Mortar Used

In all cases where this type of cracking has occurred, the formula of the mortar was practically the same, allowing for usual variations in mixing practice on the job, and was approximately 1 part by volume of Portland

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* Received August 5, 1933.

cement, 1 part by volume of high magnesium hydrated lime, and 3 parts by volume of sand.

The sand may have been varied slightly up or down to control workability, but not sufficiently to materially change other properties of the mortar. Furthermore, the above mortar contains from 25 to 30% less sand than is commonly used in cement-lime mortars elsewhere on the Pacific Coast as well as throughout the United States.

IV. Investigations Made

Investigations of every angle of this subject have covered a period of approximately four years and have been conducted independently by (1) the engineering staff of the Gladding, McBean and Company, (2) Raymond E. Davis, University of California, (3) H. G. Schurecht, National Terra Cotta Society Fellow at the U. S. Bureau of Standards, and (4) Charles Abbott Newhall, consulting chemical engineer.

Detailed reports of tests made, research conducted, and conclusions reached are on file. All agree on every essential and point definitely to the conclusions stated above.

V. Conclusive Facts Determined

A summary of the facts established by the investigation and upon which the conclusions are based are as follows:

(1) All of the usual causes of cracking in facing material, such as settlement, wind pressure, earthquake movement, etc., were first thoroughly investigated and rejected as insufficient to account for the trouble, particularly in view of the fact that many cracked pieces were discovered which carried no load whatever and could not possibly be put under a strain from any of these causes.

(2) The quality of terra cotta was carefully examined and found to be no different from that being furnished concurrently on many other buildings. All factory operations were checked for many years back and it was definitely determined that no change of any character had taken place in the body composition, firing temperatures, or other factors affecting quality.

(3) By process of elimination attention was directed to the backing material and it was discovered that the trouble existed only on buildings backed up with brick and mortar and where the mortar was compounded from approximately the above formula. Furthermore, on all buildings on which this type of cracking was discovered, investigation revealed that this one type of cement and high magnesium-lime mortar of approximately the above formula was used.

For example, on the Telephone Building, that portion of the terra cotta (typical spandrels and pier sections at the floor beam levels) which is backed up with lean cement grout shows no cracking, whereas the pier section directly above and below the level above mentioned, which has brick backing set with the above mortar, cracked badly.

On the Hunter-Dulin Building, the lower stories of which were backed up with brick and mortar similar to the above, cracking has occurred, whereas on the upper stories on which the mortar was changed at our suggestion, no cracking of this type has taken place.

(4) Simulative tests were conducted by engineers of this company in which piers 6 feet high and of exactly the same cross-section as those on the

Telephone Building were erected, backed-up with brickwork in which different mortars were used, and kept wet over a long period of time. Those piers on which mortars of the same or closely similar composition to the above were used, failed in exactly the same manner, whereas those piers erected at the same time and given the same treatment except that the mortar used in the backing was made of high calcium lime putty did not fail.

(5) Extensive laboratory tests by Raymond E. Davis, on full-sized brick masonry piers with different mortars and under different conditions of temperature and humidity, proved the statements of this company, as evidenced by the following extract in a letter dated August 16, 1929, from Professor Davis:

> There is conclusive evidence that mortars as rich as 1 part Portland cement, 1 part high magnesium hydrated lime, and 3 parts sand under the action of moisture expand sufficiently to crack badly the terra cotta facings of brick walls.

Similarly, Charles A. Newhall, above mentioned, has written regarding the Telephone Building as follows:

> It has been positively established that the expansion of mortar used in setting and backing the terra cotta is the primary cause of cracking, this expansion being caused by water entering into the mortar after it has hardened.

VI. Prevention of Cracking

In order to prevent a recurrence of this trouble on future buildings on which our terra cotta is to be backed up with brickwork, a policy has been adopted of inquiring into the formula of the mortar which it is proposed to use. If a high magnesium lime and/or a mortar unusually rich in cementing ingredients are to be used a hearing is requested, at which time all of the above facts are brought out to secure a modification of the specifications. The following specific recommendations with regard to mortars which are to be used in connection with our material are generally permitted:

For Setting Terra Cotta and Brick Backing

1 part by volume Portland cement (must pass soundness test)
1 part by volume high calcium lime (14 days old putty in preference to hydrated)
Not less than 5 parts by volume clean sharp sand

If conditions indicate the desirability or necessity of using a high magnesium hydrated lime, its use is not opposed under the above formula, but extreme caution is urged in seeing that the sand content does not fall below that called for in the formula. If such a mortar proves to have insufficient plasticity, the sand content must not be reduced. Calcium lime putty must be substituted for a portion of the high magnesium hydrated lime to whatever extent proves necessary.

If the properties of the sand being used permit, it is recommended that $5^1/_2$ or 6 parts of sand be used in preference to 5 parts as called for above.

If any brand of prepared mortar is to be used, its formula should be ascertained, and any additions of cementing materials or sand should be calculated so as to result in a mortar not richer in cementing ingredients than the above.

For Pointing Mortar	For Grout Filling (where brickwork is not used)
1 part by volume Portland cement	1 part by volume Portland cement
2 parts by volume clean sharp sand	6 parts by volume top gravel or well-graded sand
1/4 part by volume fire clay	No lime of any character
No lime of any character; color as desired.	

No cases are on record where this type of cracking has occurred when the above recommendations have been followed. It is believed that these recommended mortars, which after all are very close to average practice the country over, are perfectly safe from the standpoint of destructive volume expansion due to moisture.

GLADDING, MCBEAN, & COMPANY
LOS ANGELES, CALIFORNIA

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Abrasives

Structure and mineralogical composition of fine corundum powders for polishing. O. V. Almazov. *Mineral. Suir'e*, **8** [2], 23–27 (1933).—Data on the structure and mineralogical composition of Russian corundum powders employed for polishing and their comparison with the American abrasives are given. M.V.K.

Presentation and comparison of particle size data. E. J. Dunn, Jr., and John Shaw. *Metal Cleaning & Finishing*, **5** [7], 295–98 (1933).—The purpose of particle size measurement is to discover the true frequency distribution of particle size. The extent to which particle size data may be used depends on the accuracy with which such data are obtained. Inadequate designation of the "diameter" used in measurements limits the use or comparison of data. The measures of dispersion that are usually used in particle size work are standard deviation, coefficient of variation, coefficient of uniformity, and geometric standard deviation. The various methods of presenting particle size data which are of vital importance to abrasive and pigment manufacturers and the need for standardization of methods of particle size analysis are discussed. E.J.V.

Measuring the depth of grinding scratches. Anon. *Machinery* [London], **41**, 729–31 (1933).—Methods for measuring the depth of grinding scratches are important in the standardization of surface finishes. Neither photomicrographic methods, the use of a knife-edge stylus passed across the work in conjunction with sound, current, or oscillogram devices, nor the use of microsections is entirely satisfactory. The method of grinding optical flats until the scratches disappear involves difficulties but has given good results. F.G.H.

Measurement of abrasive hardness of metallic surfaces. R. J. Piersol. *Metal Cleaning & Finishing*, **5** [8], 321–25 (1933).—Illustrated. E.J.V.

Electrocoated abrasives. Anon. *Metal Cleaning & Finishing*, **5** [9], 391 (1933).—Electrocoated abrasives perform cleaning and surfacing duties better than ordinary abrasives because the electrostatic force which is used to imbed the grits in the adhesive sets each one so that its cutting edge is on the working surface. The electrostatic method also spaces the particles evenly over the whole surface of the backing, giving a uniform coating which makes possible the smoothest and finest of finishes. Various abrasives such as garnet, aluminum oxide, and silicon carbide will be used on electrocoated abrasives, using cloth, paper, and combination backings. E.J.V.

Methods of preparing polishing wheels. Henry R. Power. *Metal Cleaning & Finishing*, **5** [8], 345–46 (1933). E.J.V.

Curing of polishing wheels. Henry R. Power. *Metal Cleaning & Finishing*, **5** [9], 387–89 (1933).—Curing is the process of allowing the wheel, with the face recently coated with glue and abrasive, to age before use. The changes that take place during the curing of the set-up wheel are reviewed and methods of controlling them are outlined. E.J.V.

Finishing aluminum. Henry R. Power. *Metal Cleaning & Finishing*, **5** [7], 301–302 (1933).—An outline of the methods of using abrasives for blasting and finishing aluminum is given in detail. E.J.V.

[1] The abbreviation (*C.A.*) at the end of an abstract indicates that it was obtained from *Chemical Abstracts* by coöperative agreement.

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BOOK REVIEW

Mineral Raw Materials in Industry. I. Abrasive Materials. N. M. FEDOROVSKY. State Scientific Technical Mining Publishing Co., Moscow and Leningrad, 1932. 108 pp. 50 figs. Price 1 R 50 k. This is a brochure on (1) natural abrasives, *e.g.*, diamonds, corundum, rubies, sapphires, garnets, rock crystal, varieties of quartz and quartzites, crocus, tripoli, and pumice, and (2) artificial abrasives, *e.g.*, silicon carbide, corundum, etc. Besides nonmetallic abrasives, F. briefly describes alloys used for abrasive purposes. Ways of expressing the fineness of grains (mesh, etc.) and statistical data on the production of abrasives in the U. S. are presented in the conclusion.

S.I.PERKAL

PATENTS

Grinding wheel. JOHANN TUREK. U. S. 1,926,321, Sept. 12, 1933.

Grinding machine. H. G. WEINLAND (Safety Grinding Wheel & Machine Co.). U. S. 1,926,470 to 1,926,472, Sept. 12, and U. S. 1,928,145, Sept. 26, 1933. H. L. BLOOD (Heald Machine Co.). U. S. 1,926,967, Sept. 12, 1933. SOL EINSTEIN (Heald Machine Co.). U. S. 1,926,974, Sept. 12, 1933. J. R. WHITTLES (Mattison Machine Works). U. S. 1,927,007 Sept. 12, 1933. R. P. THOMPSON (W. A. Scholey). U. S. 1,927,104, Sept. 19, 1933. LOUIS SCHULTE (Allegheny Steel Co.). U. S. 1,929,101, Oct. 3, 1933. FRANZ KURATH (Economy Fuse and Mfg. Co.). U. S. 1,929,746, Oct. 10, 1933.

Machine for grinding the ends of cotton gin ribs. JOSEPH BEHLE (Murray Co.). U. S. 1,926,577, Sept. 12, 1933.

Automatic feed for grinding machines. B. F. STOWELL (Van Norman Machine Tool Co.). U. S. 1,926,603, Sept. 12, 1933.

Contour surface grinder. CARROLL KNOWLES (Pratt & Whitney Co.). U. S. 1,926,777, Sept. 12, 1933.

Rotary table grinding machine. WILLIAM LAW (Pratt & Whitney Co.). U. S. 1,926,779, Sept. 12, 1933.

Rotary grinding and polishing device. E. F. COOK. U. S. 1,926,835, Sept. 12, 1933.

Work-handling apparatus for grinding machines, etc. R. A. QUIMBY (Heald Machine Co.). U. S. 1,926,959, Sept. 12, 1933.

Honing tool. F. M. KERN (Micromatic Hone Corp.). U. S. 1,927,039, Sept. 19, 1933.

Method and machine for grinding tuning tongues. ALFRED DIX. U. S. 1,927,154, Sept. 19, 1933.

Safety razor blade sharpening machine. F. W. COCHRANE (T. D. Heyl). U. S. 1,927,392, Sept. 19, 1933.

Surface grinder. E. M. LONG (Shuron Optical Co., Inc.). U. S. 1,927,552, Sept. 19, 1933.

Speed control device for grinding machines. A. G. BELDEN AND F. E. DROWN (Norton Co.). U. S. 1,927,655, Sept. 19, 1933.

Buffing wheel. HARRY ZIMMERMAN. U. S. 1,927,862, Sept. 26, 1933.

Grinding wheel spindle reciprocating mechanism. C. G. FLYGARE (Norton Co.). U. S. 1,927,977, Sept. 26, 1933.

Precision grinding or abrading machine. H. H. ASBRIDGE (Churchill Machine Tool Co., Ltd.). U. S. 1,928,162, Sept. 26, 1933.

Segmental cup grinder wheel. L. E. KOSS. U. S. 1,928,314, Sept. 26, 1933.

Abrasive apparatus. WILLIAM STEVER (Stratmore Co.). U. S. 1,928,800, Oct. 3, 1933.

Cross-feeding mechanism for grinding machines. PETER PLANTINGA (Greenfield Tap & Die Corp.). U. S. 1,929,214, Oct. 3, 1933.

Abrasive element. W. J. ELLIS. U. S. 1,929,274, Oct. 3, 1933.

Grinding machine guide block. JOSEPH SUNNEN. U. S. 1,929,613, Oct. 10, 1933.

Device for grinding and polishing cylinders. FRIEDRICH KETTLEIN. U. S. 1,929,639, Oct. 10, 1933.

Glaze breaker. R. W. HAMILTON. U. S. 1,929,888, Oct. 10, 1933.

Abrading machine. FRANK TEBBE. U. S. 1,929,960, Oct. 10, 1933.

Gage mechanism for grinding machines, etc. H. L. BLOOD (Heald Machine Co.). U. S. 1,929,966, Oct. 10, 1933.

Size determining mechanism for automatic machines. H. L. BLOOD (Heald Machine Co.). U. S. 1,929,967, Oct. 10, 1933.

Grinding apparatus. MARK MUSGRAVE. U. S. 1,930,017, Oct. 10, 1933. An apparatus for honing the inner surface of the flange of a brake drum is described.

Adhesive to be employed in manufacturing waterproof abrasive products. JACQUES

LEMERLE (Soc. Anon. Compagnie Centrale des Émeris et Produits à Polir). U. S. 1,930,393, Oct. 10, 1933. An adhesive composition consists essentially of a mixture of drying oil and bitumen containing about 4% of the bitumen relative to the drying oil, the drying oil being oxidized.

Machine for grinding, sharpening, and polishing cutting tools and method of using. L. STEINER. Brit. 397,529, Sept. 6, 1933.

Apparatus for truing the grinding disks of grinding machines. F. WERNER AKT.-GES., AND C. JUNGE. Brit. 397,718, Sept. 6, 1933.

Method of producing abrading and grinding tools. P. HOPF. Brit. 398,073, Sept. 13, 1933.

Mounting of grinding wheels, stones, rollers, cutters, etc., on rotating shafts. RANSOME & MARLES BEARING CO., LTD., AND F. O. HICKLING. Brit. 398,094, Sept. 13, 1933.

Apparatus for grinding screw threads. AKTIEBOLAGET C. E. JOHANSSON. Brit. 398,519, Sept. 27, 1933.

Lapping machines. J. G. H. BUDD AND HOLTZAPFFEL & CO., LTD. Brit. 398,529, Sept. 27, 1933.

Buffing or polishing devices. J. F. FABREGAT. Brit. 398,725, Sept. 27, 1933.

Art and Archeology

Researches on artificial coloration of fine vitrified ware. PIERRE DE GROOTE. *Céramique*, **36** [541], 73–77 (1933).—G. presents the results of tests on coloring porcelain to suit the American demand. Blues and greens are easily obtained by the use of CoO and Cr_2O_3, respectively. Ivory is obtained with MnO_2 in a reducing atmosphere and with Fe_2O_3 and TiO_2 in an oxidizing atmosphere. Complex mixtures of MnO_2 and Al_2O_3 give rose colors which are also obtained from a natural sandstone from Thiviers.
M.H.B.

Water-soluble fluxes in glaze mixtures. BERDEL. *Keram. Rund.*, **41** [13], 157–58 (1933).—The employment of soluble fluxes such as soda, potash, borax, and saltpeter is discussed. The drying of applied glazes should proceed slowly. M.V.K.

Methods for obtaining dull enamels and the restoration of defective enamel on glass and other objects. J. F. KESPER. *Diamant*, **55** [19], 218–19 (1933).—Completely dull enamels are obtained chiefly by using large amounts of constituents containing alumina (clay, kaolin, feldspar) which are applied with a little enamel (10%). Some opacifier or color may be added to the mixture if necessary. Colored enamels may be applied on dull enamels. Opacifiers containing zirconium and clay are added to obtain a better white color. The restoration of a defective enamel is obtained by a paste consisting of 5 parts of Manilla copal, 5 parts of light Damar resin, 4 parts of Venetian turpentine, 4 parts of alcohol, and 6 parts of zinc white. The paste is applied and carefully heated after the volatilization of alcohol. Easily melting enamels, such as lead borosilicates and lead borates with additions of zinc oxide should be used for glass enameling. The preparation of such enamels is made in crucibles in electric furnaces. The enameling is done by spraying or immersing and firing in muffle furnaces.
M.V.K.

Striping. R. A. MOORE. *Enamelist*, **10** [12], 15 (1933).—The decoration of products by adding stripes of color is discussed, tracing the development of methods and equipment used up to the present time. The Moore fountain striper, introduced in 1932, gives manufacturers of enameled products a tool with which broad or fine stripes can be evenly and economically applied. E.J.V.

Standardizing turpentines for the application of decal. GEORGE A. LOOMIS. *Ceram. Ind.*, **21** [3], 131 (1933).—A study of the A.S.T.M. specifications indicates that they are too liberal for gum spirits of turpentine and should be made more strict. Results of various determinations on a series of turpentines are given. E.J.V.

New dinnerware. S. H. SLOBODKIN. *Ceram. Ind.*, **21** [3], 128–31 (1933).—Illustrated. E.J.V.

Dragnia tradition in Newcastle glass. W. A. THORPE. *Connoisseur*, **92** [383], 13–25 (1933).—The dating and attribution of glass is difficult because each period offers endless variety of form and technique. The five great English areas producing fine table glass are London, Bristol, South Staffordshire, Newcastle-on-Tyne, and Ireland. Certain styles which distinguish Newcastle glasses are (1) tall stem (short flaring bowl and stem very tall in proportion), (2) tin-hat foot (named for resemblance to soldiers' hats worn during the Great War), (3) cylinder bowl (bowl nearly cylindrical), (4) broken

air twist (in which the twist extends through only a part of the stem), (5) inset stem (in which the stem is let into the foot or a part let into a part), and (6) dripping tears (circlets of air tears in knops or in solid base of bowls). Flint glass was first made in Newcastle about 1684 by three Dragnia brothers who held their monopoly nearly a half century. Illustrated. E.B.H.

Porcelain and the Pardoes. JOHN KYRLE FLETCHER. *Connoisseur*, **92** [385], 178–79 (1933).—The article identifies and illustrates the work of Thomas Pardoe, a native of Derby, as a china decorator having a definite style of decoration, *e.g.*, flat, washy flowers, wild birds, or waterfalls in the Neath Valley. He was followed by his son William Henry Pardoe. Most of their work is signed, sometimes with the word "Warranted" added. E.B.H.

Current art notes: Oriental Ceramic Society. ANON. *Connoisseur*, **92** [383], 55 (1933).—The Oriental Ceramic Society is in process of expansion. It publishes the *Transactions* of the Oriental Ceramic Society and will have unlimited membership; an annual subscription of two guineas includes a copy of the *Transactions*. George Eumorfopoulos is president and information may be obtained from Leigh Ashton, Secy., Victoria & Albert Museum, London, S.W.S., England. E.B.H.

BOOK

Ancient Stained and Painted Glass. F. SYDNEY EDEN. Macmillan Co., New York. Price $2.50. *Ceram. Ind.*, **21** [4], 185–86 (1933).—This is a richly detailed handbook on the design and manufacture of stained and painted glass, tracing the development of the Norman, early English, decorated, perpendicular, and renaissance styles. Illustrated. See also *Ceram. Abs.*, **12** [9], 321 (1933). E.J.V.

BOOK REVIEW

Venetian Glass. A. N. KUBE. "Aquilon," St. Petersburg, 1923. 100 pp. 12 illustrations. 14 x 11 cm. This small, well printed book gives an interesting treatise on Venetian glass. In his historical review, K. indicates that the first data on Venetian glass belong to the 12th, 11th, and 10th Centuries. Its manufacture at that time was limited to ordinary glass of no art or industrial importance. An intensive development began in the 13th Century. Primarily all the glassworks were in Venice. In 1291 the Great Council decided to transport "per motivi di Sanita" these works beyond the boundaries of the town. At the end of the 13th Century all the glassworks of Venice were moved to a small island, Murano, two kilometers from Venice. In the 16th Century the art value of Murano glass was so generally accepted that the products of Murano served usually for gifts to visiting ruling persons. In the year 1480 the town Bruges, lending the Emperor Maximilian a great sum of money, took as a pledge a Murano glass vase. Some people regretted that such amazing works of art were made of material of such little value. In the 16th Century the glassworks of Venice had world renown. The glass articles of Venice were acquired as luxuries. They stimulated imitation and each country aimed to have its own glassworks. In the development of the forms of Venetian glass, K. considers that the classical period of this glassmaking was the 16th Century when the forms reached their highest development; the glass was of extraordinary thinness. The 18th Century saw a decadence in Venetian glassmaking. The masters of Murano vainly attempted to revive the traditions of the 16th Century. Leadership of Venice in this field ceased forever. The following kinds of Venetian glass are reviewed: colored, enameled, gilded, transparent, colorless, filigree, milk, agate, aventurine, mosaic, craquelé, engraved, cut, and beads (perles à rosette, etc.). Imitations of Venetian glass were made in a great number of countries in the 16th and 17th Centuries including Italy, the Netherlands, Germany, England, and France. The imitations were so excellent that in many cases it was impossible to differentiate between actual glasses of Murano and those made "à la façon de Venise." A few pages are devoted to a description of the technique of glassmaking and decoration. Twelve well reproduced illustrations of the famous Murano glassware give excellent examples of the technical skill and decorative technique of the "célèbre Verreries de Venise." The appendix gives a description of the illustrations and an index of reference literature.

S.I.PERKAL

PATENTS

Design for bottle. E. W. FUERST (Wizard, Inc.). U. S. 90,650, Sept. 12, 1933.

Design for range. IRVING GIL (Moore Corp.). U. S. 90,651, Sept. 12, 1933.

Design for tumbler. C. M. EVANS (Bartlett-Collins Co.). U. S. 90,701, Sept. 19, 1933.

Design for plate, etc. H. J. WAIN (Mayer China Co.). U. S. 90,742, Sept. 19, 1933.

Design for bathroom unit. R. L. DAVISON (J. B. Pierce Foundation). U. S. 90,837, Oct. 10, 1933.

Cements

Effect of carbon dioxide on the strength of building materials. G. E. BESSEY. *Jour. Soc. Chem. Ind.*, **52** [37], 287*T* (1933).—The methods of testing and of preparing the materials for testing are described in detail and the results are tabulated. The materials were lime-sand mortars, Portland cement-sand mortars, lime-pozzuolana-sand mortars, and sand-lime brick in various mixtures. C.H.T.

Cement with small heat of set. S. HERZ. *Z. Ver. deut. Ing.*, **77** [8], 205 (1933); for abstract see *Ceram. Abs.*, **12** [9], 322 (1933). L.T.B.

Effect of sugar on mortars. J. BASSO. *Concrete Constr. Eng.*, **28** [7], 433–34 (1933).—The effect of sugar additions on the physical and chemical properties of white-line and Portland cement mortars is discussed in detail. F.G.H.

Studies on hydrothermal syntheses of calcium silicates under pressure. III. SHOICHIRO NAGAI. *Jour. Soc. Chem. Ind.* [Japan], **36** [7], 403–407 (1933).—Further studies on the hydrothermal synthesis of calcium hydrosilicates under pressure of water vapor in an autoclave are described. The four hydrosilicates, $CaO{\cdot}SiO_2{\cdot}0.25H_2O$, $3CaO{\cdot}2SiO_2{\cdot}3H_2O$, $3CaO{\cdot}2SiO_2{\cdot}H_2O$, and $2CaO{\cdot}SiO_2{\cdot}H_2O$, were examined microscopically and by means of X-rays. The results are tabulated and shown on a ternary diagram of the system CaO–SiO_2–H_2O. For Parts I and II see *Ceram. Abs.*, **11** [5], 291 (1932). M.V.K.

Synthesis of calcium silicates. VII. SHOICHIRO NAGAI AND KEICH MURAKAMI. *Jour. Soc. Chem. Ind.* [Japan], **36** [8], 458–60*B* (1933).—The results of different experiments are tabulated. For Parts V and VI see *Ceram. Abs.*, **12** [10–11], 354 (1933). M.V.K.

French standard specifications for hydraulic binders. ANON. *Rev. mat. constr. trav. pub.*, No. 287, pp. 282–88 (1933).—A report is given on new standard specifications for hydraulic binders dealing with (1) definitions and qualities of the products, (2) methods of testing, and (3) conditions of delivery and reception. M.V.K.

Apparatus for automatically recording the setting time of cement. N. DAVEY. *Jour. Sci. Instruments*, **10** [5], 148–50 (1933).—Illustrated by photographs and specimen charts. J.L.G.

Concrete and industrial gases. F. W. FREISE. *Concrete Constr. Eng.*, **28** [5], 299–303 (1933).—The effects of various industrial gases upon cement and concrete are described in detail. Numerous refractory compositions are given as effective protective coatings for cement and concrete. F.G.H.

International dictionary of cement. C. R. PLATZMANN. *Cement & Cement Manufacture*, **6** [7], 248–51 (1933).—French, English, German, and Spanish equivalents of cement terms are given in four columns. Words from A to E are included in this issue. G.R.S.

Enamels

X-ray study of action of mill additions in fired ground-coat enamels. W. N. NOBLE. *Better Enameling*, **4** [9], 8–10 (1933).—Refractory constituents go into solution in the glass and the fineness of grinding has no effect on this solubility. Some diffraction lines are noted that are foreign to the enamel and iron alone and must be a product of reaction between enamel and iron. Illustrated. E.J.V.

X-rays for the study of porcelain enamels. W. N. NOBLE. *Better Enameling*, **4** [8], 18–20 (1933).—N. discusses the generation of X-rays, the application of crystal chemistry, and the practical application of X-rays for crystal analysis, and enumerates several methods of experimental diffraction used for analysis. Illustrated. E.J.V.

Researches on the hydrolitic stability of majolica enamels. WALTER KERSTAN. *Glashütte*, **63** [23], 390–91 (1933).—Different majolica enamels were subjected to resistance tests which gave irregular results. It was found that the present types of majolica enamels are little suited with respect to their stability. Silica has a favorable effect upon their quality, while an excessive addition of boric acid lowers the stability of the enamel. The soda content should be as low as possible. On the basis of these results, lead oxide was replaced by barium, calcium, magnesium, sodium, and potassium

oxides, boric acid, and silica. Sixty melts were tested and the water solubility, melting point, color, and specific gravity determined. The following results were found: (1) Barium series: Lead oxide was replaced by BaO up to 30%. The lowest water solubility was found with 9% BaO; the solubility increases with higher BaO content. However, the enamel obtained behaved better than pure lead enamels. (2) Calcium series: The lowest water solubility was reached with 18% CaO. This oxide does not improve the quality. The enamel with 9% CaO is difficult to fuse. (3) Magnesium series: Up to 18% of lead oxide was replaced. The lowering of the water stability began with 3% MgO; the stability decreased with further replacement. (4) Zinc series: This series showed the best results. ZnO has the best effect on the water stability. The minimum was reached with 6% ZnO. (5) Sodium series: From 7.6 to 13.6% Na_2O was added and the lead content decreased correspondingly. Through this replacement the stability was considerably lowered. After reaching a definite addition, the solubility rapidly increases. (6) Boric acid series: When replacing lead oxide by boric acid, the water stability is improved at first. The lowest solubility figure was found to be with 12.1% B_2O_3. The solubility increases suddenly and considerably when too much B_2O_3 is added. (7) Silica series: The replacement of lead oxide by silica increases water stability. It should not go beyond 30%. M.V.K.

Sodium aluminate for setting up enamel slips. W. K. CARTER. *Ceram. Ind.*, **21** [4], 184–85 (1933).—The best grade of sodium aluminate for use as a setting-up agent is a compound 99.7% water soluble, containing 92% sodium aluminate plus a controlled impurity. Plant tests as well as laboratory tests reveal advantages in its use. It is possible that this product may have some value as a frit constituent. See also article by McIntyre, Irwin, Carter, and King, *Ceram. Abs.*, **12** [8], 292 (1933). E.J.V.

Is phonolite to become a ceramic material? V. CHARRIN. *Céram., Verrerie, Émaillerie*, No. 1, p. 9 (1933).—Phonolite is a feldspathic rock of variable composition. It is made up of sanidine and nephelite with zeolites as secondary minerals and occasionally leucite replacing nephelite. It has been used in construction and is suggested as a substitute for feldspar due to its high alkali content. Many deposits are known in France. See also *Ceram. Abs.*, **12** [10–11], 357 (1933). M.H.B.

Controlling the color of third coat white. ANON. *Amer. Enameler*, **6** [6], 6–10 (1933).—One method of control necessitates an enamel milled and held for third coat work only. E.J.V.

Tin oxide. HEINRICH SASSE. *Emailwaren-Ind.*, **10** [9], 72–73 (1933).—Different methods employed for obtaining tin oxide and the determination of its opacifying power are discussed. M.V.K.

Ground-coat studies. Draining time and texture. E. P. CZOLGOS. *Better Enameling*, **4** [9], 18–20 (1933).—There exists a relationship between set, draining time, per cent water content, draining texture, and age of the enamel; a fresh ground-coat enamel will carry the maximum amount of water per gram of dry ground-coat enamel per square foot, and at this stage it has shortest draining time and smoothest draining texture. Through age alone, ground-coat enamel loses the ability to carry water per amount of dry ground per square foot. The draining texture of the enamel changes from smooth to orange peel to "V" and double drain, corresponding with the changes in water content and draining time that take place with the aging of the enamel. E.J.V.

Defects in enamels, their cause and prevention. RICHARD ALDINGER. *Keram. Rund.*, **41** [3], 29–30; [4], 47 (1933).—All defects in enamels may be attributed to (1) the enamel: (*a*) the use of an enamel unsuited to the purpose, (*b*) defective melting or grinding, (*c*) unsuitable raw materials; (2) defective iron (sheet metal or cast iron): (*a*) unsuitable composition of the metal for enameling, (*b*) faulty preparation of the metal (errors or soiling when rolling or casting), (*c*) faulty working of the iron (calcining, pickling, washing, degreasing, or blowing); (3) faulty treatment when enameling; and (4) defective shape of the raw ware. Flaws in enamel, its bursting, bursting of enameled edges, bubbles, fishscales or needle tappings, white efflorescences, pores in enamels, and dulling are discussed in detail. M.V.K.

Researches on the adherence of frit ground enamels to cast iron. W. LEMME, H. SALMANG, AND J. BRINK. *Emailwaren-Ind.*, **10** [31], 245–46 (1933).—Good adherence may be obtained with a short firing and high temperature and with longer firing and lower temperature. The firing range is narrower with increase in borax. The composition and gas content of the cast iron are important. Frit ground enamels expand considerably, their coefficient of expansion being more than twice that of cast iron. M.V.K.

Adhering strength of ground frit to cast iron. H. SALMANG. *Sprechsaal*, **66** [15], 250 (1933).—Three different frits were employed; frit A consisted of 70% quartz pow-

der and 30% borax, frit B, 70 quartz and 40 borax, and frit C, 70 quartz and 50 borax. To determine its adhering strength, a covering enamel was applied wet, a powder layer put on over it, and both layers were fired. The determination of the adhering strength was made by means of steel ball testing. Systematic tests from 750° up to maximum temperatures were made with the three frits. Besides testing the impact strength, defects such as crazing, shrinkage of the enamel, "boiling pores," etc., were investigated and the results were graphically represented. The normally ground frit A showed a low adhering strength when fired below 800°. With temperatures over 800°, good enamels were obtained within a definite firing range; the greatest adhering strength was obtained when firing to 880°. The same tests made with frit B showed a considerably narrower range, and with frit C the range was still smaller. The firing interval of the frit ground contracts with the softening of the frit, and the formation of "boiling pores" increases. The three frits were again tested after being ground finer; it was found that the range of good enamel is narrowed still further. The reactivity of the frit ground increased with finer grinding. In further tests, 60, 70, and 80 parts of sand were added to the mill. Frit A had a greater adhering strength at the maximum temperature but no extension of the firing range. The formation of "boiling pores" occurred chiefly in the enamel when the firing temperature of the frit was increased. This formation increased with the softness of the frit. It is due to the fact that the iron carbide of the cast iron disintegrates during firing and forms gases with the iron oxide. These gases escape during firing of the ground. In a soft frit the pores of the ground enamel close more rapidly than in a hard frit and the gases can no longer escape. They escape mostly during cooling, and small flaws are formed due to the change in volume of the quartz. Dilatometric measurements of the cast iron, ground coat, and enamel show that the ground coat has a considerably larger expansion than has been assumed. With increased temperature its coefficient of expansion increases to such an extent that it becomes more than twice as large as that of the cast iron between 500 and 600° on account of the β to α conversion of the free quartz. Investigations of thin sections showed that the fired ground coat contains much free quartz. M.V.K.

Adhering strength of enamel. ANON. *Keram. Rund.*, **41** [6], 72 (1933).—A general discussion is presented of the adhering strength of enamel, relationship between the coefficients of expansion of the enamel and the ground mass, and cooling requirements. See also article by Aldinger, *Ceram. Abs.*, **12** [10–11], 355 (1933). M.V.K.

Action of zinc oxide in sheet-iron cover enamels. ANON. *Emailwaren-Ind.*, **10** [30], 239–40 (1933).—A discussion is presented of the investigations of Fetterolf (*Ceram. Abs.*, **12** [8], 292 (1933)). M.V.K.

Enamels for cast iron. VIELHABER. *Emaillerie*, **1** [1], 25–29 (1933); abstracted in *Emailwaren-Ind.*, **10** [31], 252 (1933).—The way in which the enamel is prepared is important. The duration of fritting depends on the temperature, the viscosity of the mixture, and the fineness of the quartz. It is more advisable to use sand than powdered quartz. The addition to the mill must be regulated according to the thickness of the coat and to the firing temperature and its duration. The grinding fineness is important. In case of difficulties, the working conditions should be changed first and then the composition. M.V.K.

Acid-resisting enamels. LUDWIG STUCKERT. *Chem. Trade Jour.*, **93** [2408], 27 (1933).—The production of enamels highly resistant to acid has been successful only with cast iron because of the fact that the cubical coefficient of expansion of cast iron lies nearer to that of the enamel employed than does the coefficient of sheet iron. The resistance to acid of enamel increases with the rising content of silica, but this relationship is not a linear one, the curves showing distinct minima and maxima. The influence of basic oxides follows, with few exceptions, the affinity which these bases have in the free state for both water and acids. Sesquioxides, like alumina, are valued ingredients of highly acid-resistant enamels but boric acid should be as low as possible. Neither sodium fluoride nor cryolite should be used in acid-resisting enamels. Clay lowers the chemical resistance. The most satisfactory acid-resisting enamels are obtained by employing mixes as close in composition to those of Jena laboratory glass as possible. Typical compositions are given. The technology of application of the acid-resisting enamels differs from that of the ordinary enameling process only in regard to the final coat. The composition and pretreatment of the cast iron, firing, and cooling of the enamel are described. M.V.K.

Solubility test for white cover-coat enamels. ANON. *Enamelist*, **10** [11], 14–15 (1933).—Results of experiments on the solubility of white cover-coat porcelain enamel in distilled water at 145°F ± 5° for periods of 30 days at a time are given together with calculations of the life of the coating. E.J.V.

Notes on enameling. VI. A. H. *Rev. belge ind. verrières, céram., émail.*, **4** [6], 129–30; [7], 153–55; [8], 179–81 (1933).—When enameling cast iron it is necessary to (1) combine the chemical composition of the enamel in such a way that it will not react with the carbon of the iron; (2) prepare the surface of the cast iron in such a way as to reduce the effect of carbon; or (3) change the composition of the iron to eliminate or diminish the harmful constituents. These methods are discussed in detail. The treatment of iron and the preparation of cast iron for enameling are described. Data on American, French, German, and English cast iron are given, and the influence of the chief constituent of the cast iron is discussed. For Parts I–V see *Ceram. Abs.*, **12** [10–11], 356 (1933). M.V.K.

Elasticity. VIELHABER. *Emailwaren-Ind.*, **10** [23], 185–86 (1933).—Highly elastic enamels are seldom suitable for enameling. Brittleness depends on the iron and not on the elasticity of the enamel. The elasticity of an enamel is generally of secondary importance for evaluating enamels. M.V.K.

Cooling of enameled ware. R. ALDINGER. *Emailwaren-Ind.*, **10** [31], 246–48 (1933).—A. discusses the articles of Vielhaber (*Ceram. Abs.*, **12** [10–11], 356 (1933)) dealing with the cooling of fired enamel. Slow cooling is a means for increasing the durability of enameled ware. M.V.K.

Limousin enamels. GEORGES FONTAINE. *Illustration*, Vol. 89, No. 4631 (1931).—A historical description of the famous cloisonné and champlevé enamels produced in Limoges is given. Some of the enamels were produced in the 12th Century. Most of the enameled objects have a religious character. Colored illustrations. See also article by Mavor, *Ceram. Abs.*, **11** [12], 609 (1932). M.V.K.

New enamel-technical department of the State Ceramic High School of Höhr. WALTER KERSTAN. *Emailwaren-Ind.*, **10** [29], 231–35 (1933).—A description of the new enamel department of the High School of Höhr, near Koblentz, and of the work done is given. M.V.K.

BOOK REVIEW

Manufacture of Enameled Ware. V. LOKSHIN. State Chemico-Technical Publishing Co., Moscow, 1932. 96 pp. 27 figs. Price 1 R 75 k. This is the first practical manual issued in the Russian language dealing in detail with the enameling of metals. It is published in two parts. In the first part are outlined the raw materials for enamels, their properties, methods of preparation of enamels and ground coats, calculation of compositions, and methods of enameling iron and cast-iron ware. In the second part will be published the furnaces and equipment of enameling plants, and defects in enameled ware and their elimination. A special chapter will be devoted to colored and jewelry enamels. S.I.PERKAL

PATENTS

Bathtub. FRANK CAPPUCCIO. U. S. 1,929,480, Oct. 10, 1933.

Tile support and fastener. W. A. TURNER, W. R. WALLS, AND E. E. BRYAN. U. S. 1,930,023, Oct. 10, 1933.

Glass

Test for chemical resistance of glass containers. F. C. FLINT AND A. K. LYLE. *Bull. Amer. Ceram. Soc.*, **12** [10], 296–99 (1933).

Note on feldspar in sheet glass. DONALD SHARP. *Nat. Glass Budget*, **49** [20], 16 (1933).—The function of feldspar as a source of alumina in sheet glass is discussed. Because of the similarity in the silica and alkali contents of feldspar and sheet glass an alumina addition can be made by adding feldspar without disturbing the silica-alkali ratio. C.H.T.

Formation of pseudowollastonite in a tank furnace. M. BELLIÈRE. *Pottery Gaz.*, **58** [668], 231 (1933); for abstract see *Ceram. Abs.*, **12** [10–11], 367 (1933). E.J.V.

Atomic arrangement in glass. W. H. ZACHARIASEN. *Ceram. Ind.*, **20** [6], 269 (1933); for abstract see *Ceram. Abs.*, **12** [4], 145 (1933). W.W.M.

Chemical conversions in melts of soda-alkaline earth glasses. OSCAR KNAPP. *Keram. Rund.*, **41** [22], 280–82; [23], 298–99; [24], 310–12 (1933).—It was found that alkaline-earth carbonates lose carbonic acid below 400°, expel it completely below 900°, and expel soda below 1000°. No formation of silicate occurs below 800°, but a formation of water-insoluble soda alkaline earth double carbonates or double oxides takes

place. The formation of silicates of barium and magnesium is completed below 1000°. Silicates of soda and lime are formed only above 1100°. M.V.K.

Changes in alkaline solubility of fire-polished glasses by firing alkalis on the surface of the melt. A. Tielsch and E. Zschimmer. *Sprechsaal*, **66** [17], 285–86; [18], 303–306; [19], 319–22; [20], 334–37 (1933).—Experiments with colophony and pouring cobalt glass upon a white glass of the same composition show that the surface layer of the melt makes the film of drawn glass threads. Alkaline determination on threads shows that deviations in soda-lime-silicate melts generally amount to ±5 to ±10%. Control values of the hot alkaline solubility of threads from Fletcher furnace glass were determined on a series of Na_2O–CaO–SiO_2 melts from pure materials which confirmed the relationship between alkaline solubility and chemical composition found by Möller and Zschimmer (*Ceram. Abs.*, **8** [7], 535 (1929)). To determine reasons for the changed alkaline solubility in the control melts, experiments were made in an electric furnace with molybdenum wire casing. The threads of these melts produced higher alkaline solubility values than the threads from the Fletcher furnace glass. Differences in alkalinity depend on (1) the composition of the glass mass, and (2) the chemical effect of fire gases in the Fletcher furnace (SO_3 effect). The difference in alkalinity between glass threads of the Fletcher and molybdenum furnaces is due to a greater alkaline loss through firing in the Fletcher furnace. With a similar glass composition a difference in the alkalinity of the fire-polished surface in drawn or blown glassware should be expected according to whether the surface of the melt or a deeper layer in the "film" of the glass object is present during working. Thus, in the drawn process of Libbey-Owens, with a similar glass composition, the alkaline solubility is lower than for glass drawn in the Fourcault process. M.V.K.

Mixed alkali glasses. W. E. S. Turner and S. C. Waterton. *Chem. Trade Jour.*, **93** [2409], 45 (1933).—Four series of mixed alkali-lime-silica glasses containing lithia, soda, potash, and rubidia were examined for densities, coefficients of thermal expansion, annealing temperatures, and chemical solubilities. Ease and rate of melting decreased throughout the sets from lithia to rubidia, paralleling the annealing temperatures and thermal expansion factors. In the case of the density factors, potash appeared to be anomalous. The lithia and rubidia glasses were especially resistant. Densities and coefficient of expansion data were interpreted as indicating the possible existence in the glasses of compounds in which the alkali oxides were combined in the ratios $1Li_2O:2Na_2O$, $1Li_2O:2K_2O$, and $1Na_2O:1K_2O$. M.V.K.

Antimony oxide as refining agent for glass. L. Springer. *Sprechsaal*, **66** [11], 180–81 (1933); see following abstract. M.V.K.

What the glassworks technician must know about new experiments on refining agents for glass. Ludwig Springer. *Glashütte*, **63** [17], 287–90 (1933).—Saltpeter alone has no special refining action; it acts only when the refining has proceeded for a long time at a sufficiently high temperature. It is more advantageous than soda saltpeter because the latter absorbs more water and disintegrates sooner. Arsenic has a good refining effect when thrown into the melt in lumps; when powdered and mixed with the batch, the results are less satisfactory. Saltpeter and arsenic used together make an excellent refining agent. Antimony oxide alone has no refining action, but when used with saltpeter it works much better. Glauber salt acts well when used for ordinary glasses, but for alumina glasses it is unusable because of the formation of a great amount of foam. Coal improves refining. The use of sulfate and saltpeter together shortens the melting time with an increased sulfate content. Other sulfates such as aluminum sulfate, barium sulfate, or gypsum have a refining action; sulfur used alone also has a certain refining action. Common salt improves the rate of melting. Among the fluorides tested, sodium fluosilicate refines best when used with 0.4% soda. Ammonium salts shorten the melting and refining time. Their action is improved when used with chloride or nitrate, although chloride colors glass yellow. A literature index on the subject is given. M.V.K.

Barium and magnesium oxides as glassforming oxides. Anon. *Pottery Gaz.*, **58** [676], 1252 (1933).—Magnesium-containing glass has a considerable span between the flowing temperature and the real melting point, a property of importance in the preparation of mechanical glass. Barium oxide, used in suitable proportions, has a favorable effect on the physical properties of glass, density, elasticity, toughness, and resistance to breakage being improved. E.J.V.

Physicochemical principles of colored decorations for glass. III and IV. Jacques Wolf. *Rev. belge ind. verrières, céram., émail.*, **4** [6], 131–33; [8], 182–83 (1933); for Parts I and II see *Ceram. Abs.*, **12** [10–11], 363 (1933). M.V.K.

Barium nitrate as a glass decolorizer. Anon. *Pottery Gaz.*, **58** [676], 1252 (1933).—

Barium nitrate evolves oxygen at considerably higher temperatures than do the sodium and potassium salts. Barium carbonate used to replace up to 2% of alkali oxide has the effect of improving the resistance to moisture, weathering, and efflorescence on storage. It decreases the expansion under heat and improves the brilliance and color of crystal and white hollow glassware. E.J.V.

Photometric measurements of light sources of widely different colors. W. DZIOBEK AND O. REEB. *Z. tech. Physik*, **14** [9], 351–53 (1933).—By using a suitable filter it was possible to standardize sodium vapor lamps. Tungsten lamps served as standards. Results are reproducible and have been confirmed by several observers. W.M.C.

Essentials of glass technology based on American practice. I and II. SAMUEL R. SCHOLES. *Ceram. Ind.*, **21** [3], 115–17; [4], 176–82 (1933).—The glassforming oxides are discussed. Specifications for glass sand are listed. Illustrated. E.J.V.

Effect of gases on the properties of glass. V. Effect of heat treatment on the stability in water. K. NAKANISHI. *Jour. Soc. Chem. Ind.* [Japan], **36** [7], 426–27*b* (1933).—The stability of glasses heated in oxygen, air, or nitrogen and under the same conditions was found to be different. Heating in oxygen lowers stability, while heating in nitrogen is most favorable. Water saturated with oxygen has a greater dissolving action upon glasses than that without it, while nitrogen has no effect upon the dissolving action of the water. The stability of glasses heated above their softening temperature in oxygen or in nitrogen is affected by the pressure of the surrounding gases, *i.e.*, the higher the pressure, the lower is the stability. For Parts I–IV see *Ceram. Abs.*, **12** [10–11], 362 (1933). M.V.K.

Two members of the glass family: optical and chemical glasses. P. GILARD. *Rev. belge ind. verrières, céram., émail.*, **4** [6], 125–29; [7], 146–49 (1933); for abstract see *Ceram. Abs.*, **12** [10–11], 362 (1933). M.V.K.

Particle size and concentration in opal glass. E. H. RAYNER. *Rept. Nat. Phys. Lab.* [London], pp. 147–48 (1932).—A microscopical investigation of the size and concentration of the diffusing particles in a series of opal glasses has been completed. The glasses include both pot and flashed opals and cover a range of average particle size from 0.3μ to 5.0μ. The average concentrations in the glasses lie between 10^3 and 10^{13} per cc. It was found that while the particles in some opal glasses were all of the same order of size, other glasses contained two distinct classes of particles, the larger particles having a smaller concentration. For pot-opal glasses, the average particle size is a minimum at the surface of the glass and increases toward the center. The pronounced asymmetry of a distribution curve of average particle size through the thickness of the glass is due to the unequal rates of cooling on the two sides. The cooling effect is more noticeable in the case of flashed opals. Flashed opals differ from pot opals in that the maximum particle size occurs at one side of the glass, *i.e.*, at the junction of the flashing and the clear glass mounting. M.V.K.

Electrical fusion of glass. LÉON FRANCQ. *Glastech. Ber.*, **11** [7], 253–54 (1933); *Sprechsaal*, **66**, 358 (1933); for abstract see *Ceram. Abs.*, **12** [10–11], 366 (1933). M.V.K.

Thermopane insulation glass. ANON. *Arch. Rec.*, **74** [2], 26 (1933).—Thermopane is manufactured by Charles D. Haven of Milwaukee, Wis., and consists of two layers of any good glass (having at least one flat, smooth surface) with a sealed air (dehydrated) space between making the product air, water, and dust proof, providing heat insulation, and controlling moisture or frost formation. E.B.H.

Electric resistance of insulating materials subject to mechanical strain. T. AKAHIRA AND A. GEMANT. *Arch. Elektrotech.*, **27** [8], 577–85 (1933).—Electric breakdown was investigated for thin sheets of the following materials subject, at the same time, to mechanical strain: glass, mica, rubber, celluloid, and cellophane. The strain amounted from 10^3 to 10^4 kg./cm.^{2}. The electric resistance was found to increase first with an increasing pressure by a sphere, then to decrease. Uniform strain will increase the electric resistance of glass showing a small Poisson constant μ. The electric resistance of glass will decrease with the tension applied, but it will increase for rubber, μ being about 0.5. No influence of bending was found on the electric resistance. The results are explained by assuming a deformation of the molecules and a change of shape in the microscopic cavities. W.M.C.

Sculptured glass, a new architectural medium. A. E. MARSHALL. *Bull. Amer. Ceram. Soc.*, **12** [9], 289–90 (1933).

BOOK

The Glassy State. (Der Glaszustand.) G. TAMMANN. Verlag von Leopold Voss, Leipzig, 1933. 123 pp. Price 8.70 Rm. Reviewed in *Jour. Amer. Chem. Soc.*, **55** [9], 3902 (1933).—The results of numerous researches upon substances in the glassy state

are reviewed. Attention is directed to the scientific aspects of the subject with little reference to the practical side of glass manufacture. Glasses studied were chosen rather because of their suitability for the investigation than because of their practical utility. Most of the work was done upon organic glasses softening between 0 and 100°C, but T. states that the general results may be carried over into the field of the technically important silicate glasses where the higher temperatures required increase the experimental difficulties encountered. The first half of the book discusses the formation of crystallization centers, the linear rate of crystallization in supercooled liquids, and the changes which occur in all the physical properties of a glass as its temperature is increased through the interval in which it softens. It is shown that for normal glasses the physical properties in general undergo rapid but continuous changes in the interval between the temperature at which the glass ceases to be brittle and that at which it can first be drawn out into threads. The behavior of glasses under high pressures is discussed. The last half of the book contains chapters on (1) phenomena of crystallization or devitrification, (2) relation between the properties of the glassy state and the crystalline state, (3) increase in the strength of glass threads with decreasing size, (4) induced birefringence of glass surfaces, (5) molecular constitution of glasses, and (6) irreversible changes in the physical properties of glasses. F.G.H.

Book Review

The Electrical Properties of Glass. J. T. Littleton and G. W. Morey. John Wiley & Sons, 1933. x + 184 pp. 69 figs. 15 x 23 cm. Price $3.00.

This monograph is No. 3 in a series published under the auspices of the Committee on Electrical Insulation, Division of Engineering and Industrial Research, National Research Council. The names of the authors are guarantees of the authoritative character of the work. It is "primarily intended as a reference for laboratory workers interested in electrical measurements and dielectric theory," but some attention is given to glass as an engineering material for the benefit of insulation engineers.

The first chapter, comprising nearly one-third of the book, is devoted to the manufacture, composition, and properties of glass. The few pages on manufacture are obviously intended for the general information of engineers. Composition is discussed with reference to the classical work of the Geophysical Laboratory on phase equilibria in soda-silica and soda-lime-silica systems. Clear statements are made concerning the choice of glass compositions for specific purposes.

Fifty-five glass compositions, which are tabulated, are largely those of the Jena, Bureau of Standards, and Chance Brothers & Co. laboratories. The mechanical and thermal properties of 31 of these, including Pyrex chemical resistant and silica glass in addition, are tabulated. In common with other such tabulations, these fail to include any compositions representing ordinary plate, window, or bottle glasses.

The theory of the additive effect of glass composition on properties receives attention. Its limitations are noted, and the work of some investigators in selecting factors for the oxides is cited. The most acceptable sets of factors for several properties are tabulated.

The meat of the book is reached in Chapter II on Electrical Conductivity, in which the authors present concise definitions and review the published work of many investigators on this subject, covering mechanism, methods of measurement, surface and volume conductivity at low temperatures, effect of temperature, and dielectric absorption. Comment and exposition are skilfully blended in the recital. Similar treatment is given Dielectric Constant and Dielectric Loss in Chapters III and IV. A table presents the dielectric data on more than 125 glasses, with fused quartz and mineral quartz in addition, drawn from numerous sources in the literature.

Chapter V on Dielectric Strength devotes forty pages to a thorough, clear presentation of the physics of this subject, with citation of data from many experimenters. Early investigations, the effects of surrounding medium, frequency and temperature, variation with thickness, relationship with composition, nature of dielectric failure (in which is shown the striking resemblance between the appearance of a partial puncture and that of the path of natural lightning), and the dielectric strength of thick sections of glass constitute the subheadings.

This book will be welcomed by all who are interested in electrical insulators. The first chapter will be valuable to the general reader who desires a knowledge of the character of glass and a view of it as a physical material unclouded by operative detail.

The treatment throughout is completely scientific with positive statements where the facts are known and admirable restraint in matters of theory.

More than 160 names of authors and laboratories appear in the index.

S.R. Scholes

PATENTS

Glass-feeding apparatus. A. M. ALGEO (Hazel-Atlas Glass Co.). U. S. 1,926,024, Sept. 12, 1933. E. P. DORMAN (United Glass Bottle Mfrs., Ltd.). U. S. 1,926,764, Sept. 12, 1933. A. H. STEWART. U. S. 1,926,823, Sept. 12, 1933.

Pneumatic glass feeder. THOMAS STENHOUSE (Hazel-Atlas Glass Co.). U. S. 1,926,122, Sept. 12, 1933.

Glass-transfer mechanism. I. H. FREESE (Hazel-Atlas Glass Co.). U. S. 1,926,041, Sept. 12, 1933, and U. S. 1,927,087, Sept. 19, 1933.

Apparatus for making tubular glass. L. D. SOUBIER (Owens-Illinois Glass Co.). U. S. 1,926,410, Sept. 12, 1933.

Method and apparatus for producing glass containers. C. B. GARWOOD (Carr-Lowrey Glass Co.). U. S. 1,926,440, Sept. 12, 1933. A. C. FORSTER. U. S. 1,929,842, Oct. 10, 1933.

Photographic and projection lens. ARTHUR WARMISHAM (Kapella, Ltd.). U. S. 1,926,569, Sept. 12, 1933.

Leer stacker. JOHN MAYO. U. S. 1,926,593, Sept. 12, 1933.

Method and apparatus for flowing glass. THOMAS STENHOUSE (Hazel-Atlas Glass Co.). U. S. 1,927,101, Sept. 19, 1933.

Bottle-blowing machine. J. W. HARDING. U. S. 1,927,438, Sept. 19, 1933.

Method and device for making vitreous objects. S. H. PELTIER (Peltier Glass Co.). U. S. 1,927,650, Sept. 19, 1933.

Glassmelting furnace. P. L. GEER (Amco, Inc.). U. S. 1,927,658, Sept. 19, 1933.

Manufacture of footed glassware. J. H. AMBROSE. U. S. 1,927,674, Sept. 19, 1933.

Glass cutter. G. W. ALDEEN (Fyrac Mfg. Co.). U. S. 1,927,865, Sept. 26, 1933.

Glass-grinding apparatus. M. E. CARLISLE (Pittsburgh Plate Glass Co.). U. S. 1,928,005, Sept. 26, 1933. EDWARD EDWARDS AND K. W. SOMMER (Sommer and Maca Glass Machinery Corp.). U. S. 1,929,810, Oct. 10, 1933.

Apparatus for automatically supplying batch to glass tanks. H. L. HALBACH AND D. R. LIMBERS (Pittsburgh Plate Glass Co.). U. S. 1,928,016, Sept. 26, 1933.

Glass-rolling apparatus. W. G. KOUPAL (Pittsburgh Plate Glass Co.). U. S. 1,928,023, Sept. 26, 1933. W. G. KOUPAL AND C. C. WESTALL (Pittsburgh Plate Glass Co.). U. S. 1,928,024, Sept. 26, 1933.

Apparatus for rolling plate glass. G. J. NAMECHE (Pittsburgh Plate Glass Co.). U. S. 1,928,026, Sept. 26, 1933.

Feeder for abrasives. JACOB SODERBERG (Pittsburgh Plate Glass Co.). U. S. 1,928,036, Sept. 26, 1933.

Apparatus for sealing laminated glass. G. B. WATKINS AND J. H. BOICEY (Libbey-Owens-Ford Glass Co.). U. S. 1,928,160, Sept. 26, 1933.

Surfacing and polishing. FORTUNÉ BÉTRANCOURT (Soc. anon. des manufactures des glaces et produits chimiques de St. Gobain, Chauny et Cirey). U. S. 1,928,196, Sept. 26, 1933.

Apparatus for annealing continuous sheets of glass. CHARLES HEUZE (American Bicheroux Co.). U. S. 1,928,254, Sept. 26, 1933.

Forehearth for molten glass and method of controlling the temperature of the glass therein. K. M. HENRY (Hartford-Empire Co.). U. S. 1,928,288, Sept. 26, 1933.

Blister trap for glass furnaces. K. M. HENRY AND B. A. NOBLE (Hartford-Empire Co.). U. S. 1,928,289, Sept. 26, 1933.

Process and apparatus for producing sheet glass. J. L. DRAKE (Libbey-Owens-Ford Glass Co.). U. S. 1,928,371, Sept. 26, 1933.

Process and apparatus for surfacing sheet glass. T. C. MCKINLEY (Libbey-Owens-Ford Glass Co.). U. S. 1,928,385, Sept. 26, 1933.

Method and apparatus for treating insulating materials. O. F. MOTTWEILER AND C. D. RICHARDSON (General Insulating & Mfg. Co.). U. S. 1,928,388, Sept. 26, 1933.

Rotary glassmelting furnace. W. A. MORTON AND P. L. GEER. U. S. 1,928,598, Sept. 26, 1933.

Glassblowing machine. W. A. MORTON (American Glass Machine Corp.). U. S. 1,928,599, Sept. 26, 1933.

Method of making mineral wool mixture. J. B. NEAL (Johns-Manville Corp.). U. S. 1,928,699, Oct. 3, 1933.

Machine for forming glass articles. GARLAND LUFKIN AND R. G. ALLEN (Owens-Illinois Glass Co.). U. S. 1,928,730, Oct. 3, 1933.

Contact eyeglass construction. B. L. WILHELM. U. S. 1,929,228, Oct. 3, 1933.

Laminated glass. J. G. DAVIDSON (Carbide & Carbon Chemicals Corp.). U. S. 1,929,352, Oct. 3, 1933.

Apparatus for molding insulators. E. H. FISCHER (Hartford Faience Co.). U. S. 1,929,737, Oct. 10, 1933.

Composite silica article and method of making. ELIHU THOMSON (General Electric Co.). U. S. 1,930,327, Oct. 10, 1933. The process of making an article of vitreous refractory material by the accretion of particles of the material at its fusion temperature consists in feeding the particles into a fusion zone during the formation of one part of the article at a rate at which a transparent dense product results and subsequently feeding particles of the material into a fusion zone during the formation of another part of the article at a materially higher rate whereby a less transparent and less dense product is formed. A. L. R. ELLIS (General Electric Co.). U. S. 1,930,340, Oct. 10, 1933. An article of manufacture comprises a unitary article, one portion of which consists of transparent vitreous silica having a density of about 2.2 and being substantially devoid of gas inclusions, and another portion of which is translucent, having a density of about 2.0 and containing gas inclusions, the article otherwise being homogeneous in structure throughout.

Glass sheet-forming apparatus. P. J. M. ESCOLE (Forges et Ateliers de Constructions Électriques de Jeumont). U. S. 1,930,424, Oct. 10, 1933.

Apparatus for forming glass parisons. H. W. INGLE (Hartford-Empire Co.). U. S. 1,930,439, Oct. 10, 1933.

Glass grinding and polishing machine. H. J. CAPELLMAN, SR. U. S. 1,930,383, Oct. 10, 1933.

Annealing furnaces. C. E. FRAZIER. Brit. 397,729, Sept. 6, 1933.

Closures for containers of glass or other frangible material. VETRERIE RIUNITE A. BORDONI E DI SAN PAOLO SOC. ANON. Brit. 397,792, Sept. 6, 1933.

Non-refillable bottles. S. GRAUER. Brit. 397,797, Sept. 6, 1933.

Apparatus for drawing glass sheets. NAAMLOOZE VENNOOTSCHAP HOLLANDSCHE MAATSCHAPPIJ VOOR DE VERVAARDIGING VAN GLAS. Brit. 397,820, Sept. 6, 1933.

Stratified bodies such as strengthened glass. TRIPLEX SAFETY GLASS CO., LTD., AND J. WILSON. Brit. 398,172, Sept. 20, 1933.

Manufacture of laminated nonsplintering glass. IMPERIAL CHEMICAL INDUSTRIES, LTD., J. S. B. FLEMING, AND A. RENFREW. Brit. 398,189, Sept. 20, 1933.

Method and machine for gaging articles, especially glass tubes, etc. R. HADAN (Corning Glass Works). Brit. 398,457, Sept. 20, 1933.

Rollers for drawing flat sheet glass. J. GASKELL. Brit. 398,479, Sept. 27, 1933.

Structural Clay Products

Tests of reinforced brick columns. INGE LYSE. *Jour. Amer. Ceram. Soc.*, **16** [11], 584–97 (1933).

X-ray study of the toughness of paving brick. GUY E. STONG. *Jour. Amer. Ceram. Soc.*, **16** [11], 598–600 (1933).

Measuring porosity of brick and their content in soluble salts. ALIX CORNILLE. *Rev. mat. constr. trav. pub.*, No. 287, pp. 141–44*B* (1933).—Data on French standard specifications with regard to porosity and soluble salts content in brick are discussed and tests for measuring them are described. M.V.K.

Scumming of common brick and mortar. ANON. *Tonind.-Ztg.*, **57** [66], 769–70 (1933).—Scumming can be prevented by (1) avoiding the presence of soluble salts in the raw materials used for all kinds of building materials, such as common brick, cement, lime, mortar, and water, (2) adding water-refuting substances to the mortar, and (3) keeping the masonry dry by means of a well-built roof. W.M.C.

Manufacturing defects in heavy clay ware, their causes and obviation. M. PULFRICH. *Ber. deut. keram. Ges.*, **14** [2], 89–93 (1933); for abstract see *Ceram. Abs.*, **12** [10–11], 381 (1933). E.J.V.

Use of de-airing for clays and other plastic products. H. R. STRAIGHT. *Chem. Met. Eng.*, **40** [8], 410–13 (1933); see also *Ceram. Abs.*, **12** [7], 264 (1933). A.K.

Practical clayworking. V. ANON. *Brit. Clayworker*, **42** [497], 160–63 (1933).—The current article is a discussion of the manufacture of the "clamp brick" which is in favor with the architects for domestic building because of the many variations of color obtained by "clamp" firing. For Part IV see *Ceram. Abs.*, **12** [10–11], 372 (1933). R.A.H.

Standardizing hard-fired brick. MEYER. *Tonind.-Ztg.*, **57** [70], 820–22 (1933).—Results of microscopic investigations of hard-fired brick which have been used for periods

up to 50 years are discussed. Well-sintered brick showed good service value whereas inferior brick could be picked out readily by using the microscope. W.M.C.

Use of hard-fired brick in Italy. ANON. *Tonind.-Ztg.*, **57** [69], 808–809 (1933).—Hard-fired brick are being used extensively in Italy. Two interesting buildings are described. W.M.C.

PATENTS

Tile for building furnace arch roof. IGNACE CZAJKOWSKE. U. S. 1,927,257, Sept. 19, 1933.

Method and means for manufacturing brick, blocks, tile, etc. A. WANKLIN. Brit. 398,237, Sept. 20, 1933.

Refractories

Selection of clays for saggers of predetermined resistance to thermal shock and prediction of sagger life in service. R. A. HEINDL AND L. E. MONG. *Jour. Amer. Ceram. Soc.*, **16** [11], 601–606 (1933).

Sagger manufacture. EDWIN RIESS. *Keram. Rund.*, **41** [13], 160–61 (1933).—R. outlines conditions necessary for producing satisfactory saggers and discusses (1) fat bonding clay, (2) lean clay, (3) raw kaolin, and (4) grog. The working of the sagger mix, its shaping, drying, and firing are discussed. M.V.K.

Refractories. ALFRED H. LOVELESS. *Blast Fur. Steel Plant*, **21** [9], 500 (1933).—A definition of the terms "refractory" and "refractoriness" is given. Some of the fundamental desirable properties of a refractory material are listed. E.J.V.

General chemical and physical properties of refractories. J. H. KRUSON. *Power*, **74** [17], 614–15 (1931).—Data concerning physical and chemical properties of various refractories are considered. The destructive actions to which refractories are subjected in boiler furnaces are thoroughly discussed. F.G.H.

Permeability of refractory materials to gases. I. F. H. CLEWS AND A. T. GREEN. *Trans. Ceram. Soc.* [Eng.], **32** [7], 295–318 (1933).—An apparatus is described for measuring the permeability of fireclay and silica products at ordinary temperatures. A review of the literature is presented. **II.** *Ibid.*, **32** [7], 319–31 (1933).—A method is described by which the permeability to nitrogen of fireclay and silica products has been measured at temperatures up to 500°C. The decrease in permeability with rise in temperature is shown to be due to the increase in the viscosity of the gas. See also *Ceram. Abs.*, **12** [9], 331 (1933). R.H.H.P., JR.

Effect of the quality and amount of bonding clay and grog on the physical properties and especially on the mechanical strength of grog brick. S. SACHS. *Sprechsaal*, **66** [26], 435–38; [27], 453–56; [28], 469–71; [29], 487–89 (1933).—The influence of the grain size, amount, and quality of the grog and the effect of the quality of the bonding clay on some physical properties such as porosity, gas permeability, and mechanical strength of grog brick were investigated. For testing the mechanical strength, two methods were employed in which the samples were subjected to abrasion with a simultaneous attack of slag. A. Increase in the amount of grog in a clay-grog mix causes (1) lowering of the mechanical strength in the raw state, (2) decrease in resistance to pressure in the fired state, (3) lowering of resistivity to slag abrasion, (4) increase in permeability, and (5) no regularity in the behavior of pores. B. Increase in the grog grain size causes (1) lowering of mechanical strength in the raw state, (2) rapid fall in resistance to pressure in the fired state, (3) rapid fall in resistivity to slag abrasion, and (4) rapid increase in permeability. The theory that through the diminishing of the grain size brick with lower porosity can be obtained is incorrect or valid in only special cases. C. The use of nonplastic clay with a lower shrinkage produces, in contrast with the use of plastic clay with a greater shrinkage, (1) considerably smaller mechanical strength in the raw product, (2) high resistivity to slag abrasion in almost all products, and (3) lower air permeability values because of low shrinkage and fewer cracks due to shrinkage with the exception of lean mixes with porous grog. With regard to the superiority of one or the other clay, no regularity was determined when testing the resistance to pressure. D. The use of prefired (high-temperature) dense grog, in contrast with prefired (low-temperature) porous grog, effects (1) lower mechanical strength in the raw state, (2) higher resistance to pressure in the fired state, (3) higher air permeability values because of the lack of after shrinkage in prefired grog and consequently a considerably restricted difference in stresses between grog and clay, and (4) lower porosity values. No regularity was determined in the resistivity to slag abrasion, the resistivity being

greater in only one case. There is no direct relationship between the mechanical strength of the raw and fired state. There is no relationship between porosity and permeability. Permeability is chiefly related to pores found between the grains and is little affected by the porosity of the grains themselves. There is no direct relationship between resistance to pressure and the resistance to slag abrasion. Brick with lower resistance to pressure may have a higher resistance to slag abrasion than those with a higher resistance to pressure. The determination of the resistance to pressure is not sufficient for evaluating resistivity to mechanical attack because the results are influenced too little by the elasticity of the fired clay and too much by the strength of the grog grains. Through a simultaneous employment of different grain sizes of grog better results in the quality with regard to density, permeability, and mechanical strength may be obtained. M.V.K.

Testing fire brick used in industrial firings. G. ISING. *Tonind.-Ztg.*, **57** [69], 812–13 (1933).—Small test brick are cemented together by means of a mixture of silicon carbide and water-glass. A circular furnace is used in which the test brick are placed. The firing material is inserted from time to time into the space between the furnace walls and the samples. The same coal is used in carrying out the tests as in the firing of large furnaces. This method will determine the best type of refractory under given conditions. W.M.C.

New process of making refractories. MAURICE BARRETT. *Brit. Clayworker*, **42** [497], 164–65 (1933).—The nonplastics may be calcined clay, chromite, sillimanite, bauxite, etc. The bond clay, which should be a very fine grained plastic clay like ball clay, is pretreated in the form of a slip with a suitable electrolyte. The batch is made up of approximately 95% calcined clay or nonplastic and 5% of raw clay. The prepared mass has a consistency similar to loose damp sand. The construction of molds, high resistance to spalling and exactness of refractory blocks, cost, and types of clays used are discussed. R.A.H.

Special refractories. C. H. DESCH. *Rept. Nat. Phys. Lab.* [London], pp. 241–42 (1932).—Experiments are being carried out on the production of ceramic tubes for vacuum containers at and above 1600°, and impervious tubes from alumina or other pure nonsiliceous materials. The method of producing alumina articles of low porosity by firing the material at a temperature approaching its melting point has been successful. By more prolonged heat treatment, a lower firing temperature may be utilized and contamination by carbonaceous impurities from the graphite resistance furnace largely eliminated. Under this treatment recrystallization of the alumina occurs and a strong translucent body is obtained. M.V.K.

Refractory materials for working at high temperatures. EUGEN RISHKEVICH. *Glastech. Ber.*, **11** [7], 253 (1933); see also *Ceram. Abs.*, **11** [11], 571 (1932). M.V.K.

Zircon refractories. ANON. *Chem. Trade Jour.*, **93** [2411], 79–80; [2412], 98 (1933).—The methods of Karl and Le Coultre (Fr. 584,721, Nov., 1924, and *Ceram. Abs.*, **5** [2], 59; [12], 409 (1926)), Bjorkstedt (*ibid.*, **11** [11], 577 (1932)), and the investigations of Seillan (*ibid.*, **6** [7], 289 (1927)), Comstock (*ibid.*, **12** [2], 63 (1933)), and Rees and Chesters (*Trans. Ceram. Soc.* [Eng.], **29**, 309 (1930)) on the production and properties of zircon refractories are discussed. A table showing results of comparative tests made with brick of fire clay, silica, alumina, silicon carbide, and zircon is given. The mechanical strength and the softening and fusion points of zircon are higher than those of the other refractories and its hardness is only slightly inferior to that of silicon carbide. The coefficient of expansion is exceptionally low. Zircon is practically inert at ordinary furnace temperatures, being attacked only by hydrofluoric acid bisulfates. At high temperature (2000°C) it resists acid and basic slag but is attacked by silicate of iron. M.V.K.

Thorium oxide, a high-temperature refractory. O. O. FRITSCHE, H. B. WAHLIN, AND J. F. OESTERLE. *Trans. Electrochem. Soc.*, **63** [23], 281–91 (1933).—Thorium oxide, prepared from the nitrate, was used to make a crucible of special design for a study of the positive ion emission of metals at high temperatures and in a vacuum. The method is described. R.H.H.P., JR.

Effect of manufacturing conditions on the properties of magnesite brick. HERMANN SALMANG AND KARL SCHNITZLER. *Ber. deut. keram. Ges.*, **14** [2], 61–84 (1933).—Three different sintered magnesites, marked A, B, and C, were aged, pressed under three different pressures (500 kg./cm.^{2}, 1290 kg./cm.^{2}, and 2200 kg./cm.^{2}), and fired for one hour at 1400, 1500, and 1600°C. Specimens of A and C were fired to 1400 and 1500°C for 24 hr., with variations in granulation. The resulting products were tested for cold compression resistance, softening under pressure, specific gravity, porosity, thermal sensitivity, and thermal expansion in the temperature range of 20 to 800°C. Thin sections

and polished sections were examined microscopically. The cold compression resistance was increased by the increase of original forming pressure, the firing temperature, and the proportion of fine grains. Lengthening the firing time at 1400° had no appreciable effect but at 1500° a favorable effect in the cold compression resistance was noted. The true beginning of softening under pressure was determined by deduction of the expansion of the apparatus from the pressure softening curve obtained. It was 80 to 300° lower than the apparent beginning of softening under pressure. Increasing the forming pressure more than the increase of firing temperature results in a maintenance or raising of the beginning of softening. Prolonging the duration of firing at 1400° generally reduces the beginning softening temperature, while in the temperature range of 1500° the prolonging of the heat treatment improves the value somewhat. Unstable softening under pressure with a one-hour firing treatment was raised by using high forming pressures and increasing the firing temperature along with proper grain size regulation. The softening interval is generally appreciably decreased by a firing temperature of 1500°. Increasing the forming pressure permits a great shortening of the firing time without reducing the cold compression resistance or the softening under pressure values. A firing temperature higher than 1500° improves the stability at high temperatures only a little. The specific gravity increases with the increase in forming pressure and firing temperature. High forming pressure and proper grain size, together with a high firing temperature of long duration make possible an appreciable reduction in the true porosity. The heat sensitiveness of the magnesite is conditioned by the high expansion coefficient of periclase and more so by the pore spaces, their arrangement, and the stiff bridges in the melt between the individual grains which materially reduce the elasticity of the grain bond. The manufactured refractories show no cleavage cracks in the grains. The thermal expansion of magnesite from 20 to 800°C was linear in all cases. Increasing the forming pressure and increasing the firing temperature or the firing time results in a reduction of the thermal expansion up to 20%. The cause for this is to be found in the enriching of the melt by magnesia which has a considerably lower expansion coefficient in silicates and in glass than in the form of the free oxide. The microscopic examination of the polished sections of the sintered magnesite shows a well developed web-formed periclase aggregate with small inclusions of spinel which developed through the disintegration of the MgO–$MgO{\cdot}Fe_2O_3$ mixed crystals. Examination of thin sections of body A shows that by raising the firing temperature and with long firing time the melt is more finely divided, penetrates the periclase aggregate, and binds the grains together. The individual periclase grains are attacked by the flux which is thereby enriched with MgO. The flux itself is not homogeneous. Iron is present only as $MgO{\cdot}Fe_2O_3$. E.J.V.

Magnesia refractories in Canada. G. M. CARRIE AND D. W. STEWART. *Can. Mining Met. Bull.*, No. 257, pp. 541–54 (1933).—The activities of Canadian Refractories, Ltd., are outlined. Research done jointly with the National Research Council and the Canadian Dept. of Mines included (1) manufacture of basic refractory clinker, (2) beneficiation of the crude ore, (3) manufacture of basic refractory brick, (4) adaptation of the product for use in making bisulfite liquors, (5) manufacture of plastic magnesite for use in oxychloride cements, and (6) development of the refractory clinker to plastic use. The quarries and plant of the company in Grenville township, Quebec, are described. Clinker, brick, and plastic refractory products are discussed. Recent activities in refractory development are outlined. G.M.H.

Investigation of some of the refractories used in ladles and in ingot casting. I. Some characteristics of the clays used in the manufacture of runners, stoppers, nozzles, etc. J. E. PRIESTLEY AND W. J. REES. *Jour. Soc. Chem. Ind.*, **52** [38], 297*T* (1933).—Manufacturing details of some of the refractories used in ladles and in ingot casting were studied and analyses of the clays and products were made together with grading tests, etc. Test pieces were prepared from undried material for contraction-on-firing data, specific gravity, porosity, reversible thermal expansion, underload refractoriness, cone refractoriness, etc. Besides firing the pieces experimentally to note the changes in the above properties, pieces were fired in a commercial firebrick kiln with a view of correlating laboratory firings and firings under works conditions. Tables and illustrations are included. C.H.T.

Industrial material for checker brick in regenerators. BARTSCH. *Glastech. Ber.*, **11** [3], 98 (1933).—Grog containing from 25 to 45% Al_2O_3 is best for checker brick. Silica brick fail in many cases because they are rapidly destroyed by flue dust and volatilized glass ingredients. The stability of brick with 18 to 25% alumina is not always satisfactory. Sillimanite and corundum brick often fail. Pure alumina and chromite brick tend to disintegrate and silicon carbide brick slag and disintegrate. Metallic and reducible iron compounds are detrimental in brick for gas chambers. The deposition of

carbon in the brick must be prevented. A certain degree of porosity is necessary in checker brick in order for them to absorb and lose heat. Clogging of pores by carbon deposition and glazing lowers the quality of checker brick for gas chambers. M.V.K.

Modern pulverized coal furnaces; need for improved refractory linings. C. CAMPBELL. *Colliery Guard.*, **147** [3790], 289–90 (1933).—The chemical action of pulverized coal ash as effected by coal composition is discussed. The fusibility may vary from 1000 to 1500°C. The worst ash has a high iron oxide content. While some success has been had with magnesite and highly aluminous brick for linings, the cost of these and some other special brick is still quite high. The choice appears to be different compositions of silica and aluminous brick, but should a means be found for stabilizing magnesite to exposure at different atmospheres it would undoubtedly be an ideal refractory. Only the part of the furnace exposed to the blast need be lined with special brick. E.J.V.

Electric furnace refractories. F. S. RUSSELL. *Jour. Inst. Metals*, **53** [6], lxxv–lxxx (1933).—Various types of refractories are described and their use discussed for the following types of electric furnaces: (1) arc-type furnace, (2) cored induction furnace, and (3) the coreless high-frequency induction furnace. See also *Ceram. Abs.*, **12** [10–11], 379 (1933). F.G.H.

Refractory insulating brick. CHARLES TAYLOR SONS CO. *Fuels & Fur.*, **11** [5], 189 (1933).—A brick which has good heat insulating properties, is lightweight, has excellent mechanical strength with no appreciable shrinkage at 2500°F, and which can be used up to 2500°F without a protecting course of fire brick is announced. E.J.V.

BOOK REVIEWS

Saggers and Gypsum Molds Manufactured in the Porcelain-Earthenware Industry. I. I. ROMANKEVITCH. "Ukrainian Worker," Kharkov, U.S.S.R., 1931. 60 pp. 20 figs. Price 25 k. The section on sagger manufacture includes recipes and methods for sagger mending. The second section describes varieties of gypsum, their calcination, and methods of gypsum mold manufacture. S.I.PERKAL

Furnaces for Melting Nonferrous Metals. D. VOYEIKOV. State Scientific Technical Publishing Co., Moscow, 1932. 143 pp. 100 figs. Price 1 R 50 k. The first chapter gives the classification of furnaces and discusses how to select a proper type of furnace for a special purpose. The second chapter deals with fuels and their combustion. Two chapters are devoted to a detailed description of crucible and reverberatory furnaces. Data on the refractory materials, methods of lining, and their destruction are of especial interest. S.I.PERKAL

Refractory Materials. R. L. PEVSNER. State Scientific Technical Publishing Co. of the Building Industry, Moscow, 1932. 44 pp. Price 1 R. The brochure deals with refractory clays and methods of manufacturing refractory clay, silica, and magnesite brick. The All-Union Standards (OST) on refractory clay and silica brick are appended. S.I.PERKAL

PATENTS

Process of manufacturing highly refractory products. V. M. GOLDSCHMIDT AND KARL SIEDENTOPF (Metallgesellschaft A.-G.). U. S. 1,926,094, Sept. 12, 1933. A process of manufacturing highly refractory products comprises mixing coarse granular natural products rich in magnesium orthosilicate, such as olivine, with a finely ground material consisting of natural products rich in magnesium orthosilicate and of substances rich in magnesium, such as magnesite, and firing the mixture to produce a highly refractory product substantially free from troublesome changes in volume, the firing being conducted by heating to temperatures sufficiently high to effect cohesion of the particles while avoiding conversion into a molten state.

Process for extracting alumina. R. F. JAMES (Detroit Edison Co.). U. S. 1,927,744, Sept. 12, 1933.

Checker brick. C. H. HUGHES (Semet-Solvay Engineering Corp.). U. S. 1,927,834, Sept. 26, 1933.

Process of making porous articles consisting of silica. GEORGE KING (Albright & Wilson, Ltd.). U. S. 1,928,021, Sept. 26, 1933. A process for the manufacture of porous articles consisting solely of silica comprises mixing silica with a soluble body and a liquid binder derived from a silicon ester, molding the mixture to the required form and allowing it to set, and finally extracting by a solvent the soluble body from the mass which has set.

Furnace lining anchor. W. H. GAYLORD, JR. (Quigley Co., Inc.). U. S. 1,928,313, Sept. 26, 1933.

Furnace wall. J. E. MACDONALD (F. B. Pope). U. S. 1,929,073, Oct. 3, 1933.

Pottery product. MAX HAUSER. U. S. 1,930,095, Oct. 10, 1933. A container is described having acid-resisting properties, high thermal conductivity, and high resistance to breaking during temperature changes, the container walls comprising a fired mixture of discrete particles of finely ground or granular silicon bonded together by a matrix of ceramic raw material of the silicate type.

Manufacture of fireclay brick, blocks, slabs, tile, etc. MORNINGSIDE FIRECLAY CO., LTD., AND R. CURRANS. Brit. 397,977, Sept. 13, 1933.

Terra Cotta

Polychrome terra cotta. WALTER TIMMERMAN. *Bull. Amer. Ceram. Soc.*, **12** [9], 276–80 (1933).

Recent developments in architectural ceramics. J. B. HELME. *Bull. Amer. Ceram. Soc.*, **12** [9], 281–83 (1933); see also *Ceram. Abs.*, **12** [6], 221 (1933).

Manufacture of terra cotta wall block. P. W. LEE. *Bull. Amer. Ceram. Soc.*, **12** [10], 301–303 (1933).

Engobe and glaze for fire clay. MATHIAS REITZ. *Keram. Rund.*, **41** [14], 178 (1933).—The engobe consists of 47 parts kaolin, 8 chalk, 10 feldspar, and 35 quartz. The Seger cone formula used is

$$\left.\begin{array}{l}0.1230\ K_2O\\0.0640\ Na_2O\\0.7933\ CaO\\0.0197\ MgO\end{array}\right\}\ 2.0905\ Al_2O_3\quad 10.5885\ SiO_2$$

The shrinkage amounts to 3.4% at Seger cone 9. After the drying of the engobed body it is polished and glazed. The glaze used is composed of 40.2 parts feldspar, 28.8 quartz, 14.0 calcite, 10.10 kaolin, 3.0 ZnO, and 4.0 SnO_2. See also *Ceram. Abs.*, **12** [9], 332 (1933). M.V.K.

Dry pressing of roofing tile. ANON. *Tonind.-Ztg.*, **57** [72], 845–46 (1933).—A plant in Hungary has been using hydraulic presses for a number of years for roofing tile. The most difficult problem was found to be the firing of the products in a ring kiln. W.M.C.

Drawing office in a terra cotta plant. F. THEILMANN. *Tonind.-Ztg.*, **57** [73], 856–59 (1933). W.M.C.

Discolorations and efflorescences in tile. E. MOTSCHMANN. *Keram. Rund.*, **41** [15], 185–87 (1933).—The causes of efflorescences are enumerated. Remedies against their appearance are (1) exact control of raw materials and water used with regard to soluble salts, (2) removal of coarse impurities (pyrite, gypsum, and mica) from the clay, (3) exact and careful firing (S content of the fuel), and (4) obtaining dense bodies. Cases from practice are described. M.V.K.

Scientific study of principal products for house floorings. VI. F. CHALAMEL. *Rev. mat. constr. trav. pub.*, No. 286, pp. 124–26*B* (1933).—The results of microscopic examinations of the structure of ceramic products employed for flooring are discussed. **VII.** *Ibid.*, No. 287, pp. 147–50*B* (1933).—The quality and defects of various products employed for flooring are discussed. For Parts IV–V see *Ceram. Abs.*, **12** [10–11], 381 (1933). M.V.K.

Manufacturing defects in stoneware production, their causes and prevention. H. HARKORT. *Ber. deut. keram. Ges.*, **14** [3], 120–28 (1933).—A general discussion is given of causes of defects which make stoneware unsalable, and methods of preventing their occurrence. The causes are traced through all phases of production. E.J.V.

Improved chemical stoneware. ANON. *Chem. Met. Eng.*, **40** [8], 433–34 (1933).—A new grade of chemical stoneware is described whose physical properties, according to the manufacturers, have been greatly improved through the use of certain electrical, mechanical, and chemical practices. A.K.

Should stoneware be fired in a reducing atmosphere? E. TUSCHHOFF. *Keram. Rund.*, **41** [8], 96–98; [10], 125–26 (1933).—Methods of firing stoneware are discussed and cases from practice are cited. See following abstract. M.V.K.

Reduced firing of stoneware. ANTI DAHL. *Keram. Rund.*, **41** [13], 158–60 (1933).—A discussion is presented of observations made during the firing of stoneware. See also *Ceram. Abs.*, **12** [7], 269 (1933). M.V.K.

Firing stoneware products. J. KLUG. *Tonind.-Ztg.*, **57** [67], 783–84; [70], 825–26 (1933).—Stoneware pipes should be fired in a reducing atmosphere and other stoneware products partly in a reducing and partly in an oxidizing atmosphere. Colored stoneware products should be fired in an oxidizing atmosphere only. See also article by Selzer, *Ceram. Abs.*, **12** [10–11], 381 (1933). W.M.C.

PATENTS

Type of pottery to grow plants indoors or outdoors. J. F. M. BURFORD. U. S. 1,928,810, Oct. 3, 1933.

Sound absorbing material and method of making. E. T. HERMANN. U. S. 1,929,425, Oct. 10, 1933. The method of making sound-absorbing material comprises mixing a mineral aggregate with a fusible ceramic bonding material in only sufficient quantity to coat the particles of the aggregate, forming a shaped body from the mixture, and heating the body to a sufficient temperature to fuse the bonding material.

White Wares

X-ray study of porcelains and their relation to mullite. A. J. BRADLEY AND A. L. ROUSSIN. *Ber. deut. keram. Ges.*, **14** [1], 50–51 (1933); for abstract see *Ceram. Abs.*, **12** [10–11], 382 (1933). E.J.V.

Effects of particle size of a potter's "flint" and a feldspar in white ware. R. F. GELLER, D. N. EVANS, AND A. S. CREAMER. Bur. Stand. *Jour. Research*, **11** [3], 327–40 (1933).—In general, the workability is decreased by using fine fractions of flint and feldspar. There is comparatively little difference in linear shrinkage during drying. Varying the specific surface of the feldspar does not greatly affect the shrinkage during heating at any one temperature; the maximum increase was from 5.9 to 7.5%. The effect on apparent porosity is also relatively small; the maximum reduction was from 18.4 to 13%. This indicates, for a body containing only 15% feldspar, that feldspar of less than 10 microns diameter can be substituted for one of the same chemical composition but of average present-day commercial fineness without greatly altering the ultimate structure of the body. The effects of varying the mean particle size or specific surface of flint only are more pronounced; the maxima were from 6.4 to 10% increase in linear shrinkage and from 18.5 to 2.8% reduction in apparent porosity. The greater effectiveness of the flint is in harmony with the fact that the bodies contain 35% flint and only 15% feldspar. Using increasingly finer fractions of both flint and feldspar produces a maximum increase in shrinkage from 6 to 11.6% and a maximum reduction in porosity from 18 to 0%. Transverse strengths varied between the extreme modulus of rupture values of 5600 and 1900 lb./in.^{2}, respectively, for bodies heated at 1150°C, and 10,800 and 4300 lb./in.^{2} for the same bodies heated at 1350°C. Linear thermal expansion determinations warrant the generalization that thermal expansion may be influenced greatly by extremes in particle-size of flint and feldspar. The use of flint containing no particles of less than 35 microns diameter may produce bodies of unusually low expansion when compared with bodies of similar composition but containing much finer flint. The effects of particle size variations on relative fusion and solution in the body structures were well defined when observed microscopically. The data obtained indicate the possibility of vitrifying commercial ceramic white ware with more finely ground materials and without the use of auxiliary fluxes at temperatures significantly lower than are now required in the industry. R.A.H.

Effect of varying the ratio of soda ash to sodium silicate in alkaline earthenware slips. J. H. RIGBY. *Trans. Ceram. Soc.* [Eng.], **32** [7], 337–47 (1933).—An attempt is made to correlate the viscosity of earthenware slips containing various percentages of soda ash and sodium silicate with the casting rate. R.H.H.P., JR.

Crazing in the white ware industry. S. G. PULIESO. *Ber. deut. keram. Ges.*, **14** [3], 105–16 (1933).—Factors which effect the development of crazing in white ware are the difference in expansion coefficients of the body and the glaze, the different courses of expansion of the body and the glaze, the tensile strength and elasticity of the glaze, and the degree of formation of an intermediate layer between the body and the glaze. To show what causes crazing P. discusses the topic under the following phases: (1) effect of the fineness of grinding of the body, (2) effect of the biscuit firing temperature, (3) effect of the porosity of the body after biscuiting, (4) effect of the temperature and duration of the glost firing, (5) effect of the consistency of the glaze in connection with the degree of glost fire and the tendency toward crazing, and (6) the effect of the conduct of muffle firing on craze formation. E.J.V.

De-airing dinnerware bodies. GEORGE A. LOOMIS. O. S. U. Eng. Expt. Sta. *News*, June, 1933; *Ceram. Ind.*, **21** [3], 136–38 (1933).—Three bodies, including a regular ivory body of a semiporcelain or earthenware, a special earthenware body, and a vitreous body, were studied for the effect of de-airing on dinnerware bodies. Several advantages that were evident are as follows: (1) The improved workability of the evacuated body is a decided advantage enabling the jiggerman to turn out satisfactory ware with greater ease and making it easier to produce thin ware. (2) The evacuated body remains in condition for jiggering longer than the normally pugged body. (3) The tendency of a body to crack in drying may be reduced or eliminated by evacuation. E.J.V.

Lowering the firing temperature of high-tension porcelain. A. N. EGOROV AND I. M. TIKHOMIROV. *Keram. i Steklo*, **9** [6], 10–13 (1933).—Experiments show that porcelain mixes with a high content in feldspar have a high electrical and mechanical strength, are more stable than siliceous mixes, and require a low firing temperature (Seger cone 10–11). Data on brown and green glazes are given. M.V.K.

Manufacturing defects, their causes and prevention in porcelain production. R. RIEKE. *Ber. deut. keram. Ges.*, **14** [3], 128–34 (1933); for abstract see *Ceram. Abs.*, **12** [10–11], 383 (1933). E.J.V.

Note on porcelain insulators. J. K. GILLETT. *Pottery Gaz.*, **58** [676], 1224 (1933).—The microstructure of the insulation medium is of importance in breakdown prevention. Extreme care is required during the firing of insulators. Tests on known porcelains show that best electrical performance is given by those insulators which are most free from "free" quartz particles. Another important factor is glaze fit. External causes of failure are the breakdown of the porcelain from an electrical point of view and the collapse of complete insulation. Breakdown may be due to oscillations of high frequency superimposed on the power frequency currents, the oscillations originating from dirt or moisture on the insulator. Deposition of dirt is always a factor to be contended with. E.J.V.

PATENTS

Insulator. L. T. WILSON (American Telephone and Telegraph Co.). U. S. 1,927,106, Sept. 19, 1933.

Siphon jet flushing nozzle, water closet, flushing valve, and bidet combination. C. C. CAMPUS. U. S. 1,928,717, Oct. 3, 1933.

Closet bowl construction. C. R. WINSTANLEY. U. S. 1,929,131, Oct. 3, 1933.

Water closet. OLOF LUNDBERG. U. S. 1,930,012, Oct. 10, 1933.

Tiled curbs, fireplaces, and slabbed hearths. T. SHEPHERD. Brit. 397,616, Sept. 6, 1933.

Securing tile, slabs, etc., to surfaces. G. E. HEYL. Brit. 397,678, Sept. 6, 1933.

Pressing clay thimbles used for holding pottery in kilns. H. M. AYNSLEY AND H. SHUFFLEBOTHAM. Brit. 397,737, Sept. 6, 1933.

Tea, coffee, hotwater pots, etc. R. B. HEPBURN. Brit. 398,496, Sept. 27, 1933.

Equipment and Apparatus

Spectroscopic apparatus in industry. C. C. NITCHIE. *Mech. Eng.*, **53** [2], 123–26 (1931).—The principles and use of the spectroscope are explained. F.G.H.

Quantitative microscopic methods with an integrating stage applied to geological and metallurgical problems. F. E. THACKWELL. *Econ. Geol.*, **28** [2], 178–82 (1933).—The integrating stage for use in summing up the proportional amounts of as many as six constituents of a powdered mixture at one time is described and its use explained as applied in the microscopic analysis of rock or ore powders. It is made by E. Leitz, Wetzlar, Germany. Illustrated. J.L.G.

G. E. recording color analyzer. L. C. ATHY AND J. L. MICHAELSON. *Amer. Enameler*, **6** [6], 3–5 (1933).—The recording color analyzer is a photoelectric device which automatically plots a spectrophotometric curve on the visible spectrum, *i.e.*, between 400 and 700 millimicrons. The application of this device to problems of vitreous enamel is discussed. Illustrated. See also *Ceram. Abs.*, **11** [11], 553 (1932). E.J.V.

Use of a simple Duboscq instrument for colorimetry, nephelometry, and the colorimetric determination of hydrogen-ion concentrations. J. GRANT. *Jour. Sci. Instruments*, **10** [4], 106–10 (1933).—Illustrated. J.L.G.

Corona wind in electric filters. W. DEUTSCH. *Physik. Z.*, **34** [11], 448–53 (1933).—

The theory developed by D. is extended to filters in which wires and plates are arranged alternatively. Theoretical and practical results agree well. See following abstract. W.M.C.

Density of unipolar ion currents. W. DEUTSCH. *Ann. Physik*, **16** [5], 588–612 (1933).—This paper deals with the theory underlying the construction of electric filters. Equations are derived for a small space charge. The theory is applied to the following arrangements: (1) thin emitting wire, parallel to a plane, (2) emitting edge opposite a plane, (3) corona discharge between two concentric spheres, and (4) thin emitting wire between two parallel planes. The integration of the equations may be derived by a graphic method. W.M.C.

Response of thermocouples. N. P. BAILEY. *Mech. Eng.*, **53** [11], 797–804 (1931).—The effects of temperature gradients in the hot junction and of varying temperatures on the indications of a thermocouple are studied. F.G.H.

Standard-cell comparator, a specialized potentiometer. H. B. BROOKS. Bur. Stand. *Jour. Research*, **11** [2], 211–31 (1933).—The standard cell plays an important rôle in the maintenance of the electrical units and in correlating the units of the various national laboratories. Modern standard cells have attained such a high degree of reproducibility and permanence as to warrant the use of apparatus of the utmost precision and reliability in their intercomparison. The present paper describes a new potentiometer developed especially for this purpose. Although it actually measures the small difference between the known e.m.f. of a reference cell and that of the cell under test, it contains a simple mechanical computing feature which automatically adds this small difference algebraically to the e.m.f. of the reference cell and thereby indicates directly the value of the e.m.f. under measurement. The new instrument has been given the distinctive name, "standard-cell comparator." R.A.H.

Mechanical analysis of raw materials used in ceramics. MARC LARCHEVÊQUE. *Céramique*, **36** [542], 101–17 (1933).—Methods and apparatus for the mechanical analysis of ceramic raw materials are presented. These include the measurement of grain size by screening, levigation, and sedimentation. The relation of grain size to the nature of the material is discussed. M.H.B.

Small drier to check up drying troubles. EARL PAGETT. *Brick Clay Rec.*, **83** [3], 90–91 (1933).—A small experimental humidity drier built to enable engineers to make short time tests on drying ware in order to test the efficiency of new dies is described. All kinds of drying conditions can be obtained. Illustrated. E.J.V.

Innovations and progress in the construction of ceramic machines. GEORG HELM. *Ber. deut. keram. Ges.*, **14** [7], 279–302 (1933).—A description is given of (1) countercurrent rapid mixers, (2) different types of presses, (3) automatic machines for shaping cups and plates, and (4) driers. M.V.K.

Noteworthy arrangements in American fine ceramic plants on the basis of recent publications. G. HELM. *Ber. deut. keram. Ges.*, **14** [4], 163–69 (1933).—Modern devices recently put into use in American ceramic plants producing quality ware are described. E.J.V.

Rubber linings for rotary grinding mills. W. E. BENNETT. *Mining & Met.*, **14** [321], 399–400 (1933).—Advantages and limitations of three types supplied by the B. F. Goodrich Rubber Co. are enumerated. Illustrated. See also *Ceram. Abs.*, **11** [9], 483 (1932). E.J.V.

Importance of nonporous grinding materials. DAVIDGE H. ROWLAND. *Amer. Enameler*, **6** [5], 5–6 (1933).—The development of nonporous electrical porcelain at the Locke Insulator Co., problems encountered, and tests the product must pass are discussed. Illustrated. E.J.V.

Dust system cleaned mechanically. ALLINGTON AND CURTIS MFG. CO. *Foundry*, **61** [3], 68 (1933).—A dust-collecting system having a self-cleaning main mechanically operated is described in detail. F.G.H.

Air separator. A. B. HELBIG. *Cement & Cement Manufacture*, **6** [7], 233–35 (1933).—A comparison is made of the fine material produced in the multi-chamber mill and that in the air separator. Results given in tables show that the percentage of fine and finest flour in the mill product is limited in the multi-chamber mill and unlimited in the air separator. G.R.S.

Operation and maintenance of cloth-screen dust collectors. W. F. TERRY. *Heating, Piping, Air Conditioning*, **5** [5], 259–60 (1933).—Illustrated. J.L.G.

BOOK

Photomicrography; an Introduction to Photography with the Microscope, with a Section on Motion Photomicrography. 12th ed. Eastman Kodak Co., Rochester, N. Y., 1933. 86 pp. Price 50¢. *Jour. Inst. Metals*, **53** [5], 283 (1933). F.G.H.

PATENT

Method of activating clay. F. W. HUBER. U. S. 1,926,148, Sept. 12, 1933.

Kilns, Furnaces, Fuels, and Combustion

Rapid volumetric method for the determination of sulfur in coal and coke. E. L. SKAU AND I. L. NEWELL. *Ind. Eng. Chem., Anal. Ed.*, **5** [3], 180–82 (1933).—A new modification of the benzidine sulfate method has been developed. F.G.H.

Correlation between calorific value and density of fuel oils. L. SMITH. *Rept. Naval Boiler Lab.*, Test No. 2132; abstracted in *Mech. Eng.*, **55** [9], 577 (1933).—Results of this investigation show that the Sherman and Kraff formula for the correlation of calorific value and density of fuel oils predicts too high a calorific value for a given density. The calorific values of fuel oils actually obtained by calorimetry were used in deriving a formula which is considered to be correct. F.G.H.

Chemistry of water gas. F. FISCHER, H. PICHLER, AND R. REDER. *Brennstoff-Chemie*, **13**, 346–50 (1932); *Gas Age-Rec.*, **72** [9], 196 (1933). E.J.V.

Contribution to the graphic control of the operation of gas generators. W. OSTWALD. *Feuerungstechnik*, **21** [6], 81–84 (1933).—A theoretical discussion is presented illustrated by diagrams. M.V.K.

Use of coal in the ceramic industry. H. E. NOLD. *Mining & Met.*, **14** [322], 432 (1933).—High volatile coals are most desirable for kiln firing. Low volatile and even anthracite coals can be used successfully. Most periodic kilns use coal and are hand fired. Continuous tunnel kilns reduce fuel consumption 40 to 55%. The ceramic industry uses from 12,000,000 to 12,500,000 tons of coal per normal year. Sales by coal producers could be increased by furnishing expert firing instruction. E.J.V.

Temperature measurement. W. LIESEGANG. *Ber. deut. keram. Ges.*, **14** [4], 170–87 (1933).—L. discusses Seger cones and temperature-measuring apparatus and their economy. The choice of proper measuring apparatus for ceramic driers and kilns is stressed. The importance of the absorption of ceramic materials in optical measurements and various recording apparatus are described. Illustrated. E.J.V.

Century of progress in fuel technology. O. P. HOOD. *Mech. Eng.*, **55** [6], 339–44 (1933).—Developments in the utilization of our major fuels during the past century are described and illustrated. F.G.H.

Use of heat from the ring kiln in drying common brick. SCHIRM. *Tonind.-Ztg.*, **57** [67], 782–83 (1933).—Pipe lines are emphasized in the floor and the walls of the ring kiln as well as on top of it. The pipe lines will show a thermal expansion different from that of the masonry and should therefore be imbedded in loose gravel, etc. W.M.C.

Constructing furnaces for the ceramic industry. F. DETTMER. *Tonind.-Ztg.*, **57** [68], 794–95 (1933).—General rules to be applied are discussed. A permanent cooperation is emphasized between the builder of the furnace and the manufacturer of ceramic products. W.M.C.

Origin of the open ring kiln. J. DOUFRAIN. *Tonind.-Ztg.*, **57** [73], 860 (1933).—An ordinary ring kiln built in Hungary showed many cracks in the crown. Rost built the first open ring kiln and invented the ring kiln with an upper flue. W.M.C.

Kiln masonry without joints. R. KUNZ. *Tonind.-Ztg.*, **57** [71], 837–38 (1933).—K. points out that, in many cases, a jointless furnace lining or one with very small joints is not necessary. The charge of the kiln will destroy the upper layers of the masonry and sinter the rest of the lining into one solid block. This is true for blast furnaces, open-hearth furnaces, coke furnaces, etc. Rejecting refractories whose edges are not smooth and straight is an unnecessary waste. W.M.C.

Fundamentals and economies in the clay industries. XXX. ELLIS LOVEJOY. *Clay-Worker*, **100** [2], 54 (1933).—Different types of continuous kilns are described and their operating problems are discussed. See also *Ceram. Abs.*, **12** [10–11], 389 (1933). C.H.T.

Flue construction for kilns. J. B. NEALEY. *Fuels & Fur.*, **11** [5], 175–77 (1933); see Youngman and Pierce, *Ceram. Abs.*, **11** [10], 539 (1932). E.J.V.

Pottery firing by tunnel ovens. T. TALBOT, A. N. TARRANT, R. WHITFIELD, AND FRANK PERRY. *Pottery Gaz.*, **58** [675], 1117–19 (1933).—The need for a smaller tunnel kiln for the smaller manufacturer is stressed. While exponents of tunnel kilns list their advantages, P. points out advantages obtainable only in intermittent kilns. E.J.V.

Books

Energetics of Gas Technology. (Energetische Grundlagen der Gastechnik.) J. Schuster. W. Knapp, Halle, Germany. 254 pp. Price 17 Rm. *Colliery Guard.*, **147** [3792], 412 (1933).—The introduction deals with the fundamentals, temperature, pressure, energy, entropy, laws of mixtures, reactional velocity, equilibrium, electrical units, transformation of chemical into electrical energy, etc. The section on heat discusses (1) various points connected with the heating and cooling of gases without chemical reaction or alteration of phase, (2) evaporation, condensation, absorption, and adsorption, and (3) reactions between gases, between liquids and solids with and without gases, and reactions in which gases are formed from liquids and solids. The section on work includes compression, expansion, and liquefaction without chemical reaction, reactions under pressure, and the chemical separation of suspended particles. The electrical section deals with gas electrodes, the electrolysis of solutions and melts, the generation of gases from solids by electricity, and the electrical deposition of suspended particles. The appendix contains tables relating to the weight of gases, saturation pressure of steam and gases, reduction to standard temperatures and pressure, mean specific heat of coke, heat conductivity of metals, nonmetallic solids, liquids, gases, and vapors, radiation, calorific values of gases, and a number of conversions of pressures and thermal units. E.J.V.

Methods for the Quantitative Analysis of Coal Ash. J. G. King and H. E. Crossley. H. M. Stationery Office, England. Price 6d. Dept. Sci. Ind. Research *Bull.*, No. 28; *Colliery Guard.*, **147** [3790], 329–31 (1933).—An outline of analytical methods is given. E.J.V.

Gas Analysis by Measurement of Thermal Conductivity. H. A. Daynes. Macmillan Co., New York, 1933. Price $4.25. *Ind. Eng. Chem.*, **25** [10], 1181 (1933); for abstract see *Ceram. Abs.*, **12** [10–11], 388 (1933). F.G.H.

Patent

Means and method of heat treating ceramic materials. Joseph Harrington (Joseph Harrington Co.). U. S. 1,927,830, Sept. 26, 1933. An external furnace for supplying heated gases under pressure in excess of atmospheric pressure, means for conducting the heated gases into the kiln chamber, whereby the pressure of the gases in the kiln chamber will be maintained above atmospheric pressure, and means for varying the thickness of the fuel bed within the furnace to control the oxidizing and reducing actions within the kiln chamber are described.

Geology

Classification of sedimentary clays. Jacques de Lapparent. *Compt. rend.*, **195**, 257–58 (1932); abstracted in *Feuerfest*, **9** [6], 88–89 (1933).—Clay beds originated by sedimentation may be divided into three main groups, halloysite, montmorillonite, and kaolinite. The first group is found in secondary beds and the second and third groups are found in primary deposits. The bulk of the original sedimented materials consists of basic and alkaline silicates (free from titanium), probably feldspar. From the humous materials observed in the kaolinite clays, it follows that these originated in a climate in which mineral coal woods existed, while the montmorillonite clays originated in deserts. The halloysite clays originated in tropical or subtropical climates from phyllitic materials. M.V.K.

Ceramic properties of kaolin. H. Lehmann. *Ber. deut. keram. Ges.*, **14** [4], 155–62 (1933).—Seven varieties of kaolin were studied. E.J.V.

Studies on the zeolites. II. Thomsonite (including faroelite) and gonnardite. M. H. Hey and F. A. Bannister. *Mineralog. Mag.*, **23** [137], 51–125 (1932).—Chemical, optical, and X-ray studies of a number of thomsonite specimens have led to the conclusion that thomsonite and faroelite form a continuous isomorphous series. The true symmetry of thomsonite is shown to be didigonal polar (C_{2v}). The unit cell is shown to contain 80 oxygen atoms and (in the fully hydrated mineral) 24 water molecules; the silicon and aluminum contents are variable, but the sum of silicon and aluminum is constant and equal to 40. The sodium and calcium contents are also variable, but the sum of calcium and sodium is normally 12. Thomsonite appears to be essentially $Na_4Ca_8Al_{20}Si_{20}O_{80}\cdot 24H_2O$, with two isomorphous replacements, $CaAl \rightleftharpoons NaSi$ and $Ca \rightleftharpoons Na_2$. The most siliceous member observed appears to have 17.4 atoms Al per unit cell, while the $Ca \rightleftharpoons Na_2$ substitution leads to variations in the sum of calcium

and sodium from about 10.3 to 14.8 atoms per unit cell; material with this sum between 11.5 and 12.5 is most common. There is a marked pseudo-cell with c-axis half that of the true cell and, to correspond, half the atomic contents. The refractive indices of thomsonite vary considerably, falling with increase in the Si : Al ratio, and the mean refractive index ranges in the specimens studied from 1.517 to 1.535. There is reason to believe that the usual diagnostic criterion for thomsonite is not invariably true, and that thomsonites may occur in which the optic axial plane is parallel instead of perpendicular to the elongation. There is a considerable probability that such material has been observed but passed unrecognized at least once. Apparatus has been designed and applied to measure the vapor pressure of thomsonite at various temperatures and degrees of dehydration, and it appears probable that a dimorphous high-temperature form (probably identified with the metathomsonite of F. Rinne) exists, the transition being readily reversible. A few experiments on the absorption of vapors other than water by dehydrated thomsonite and on the base-exchange reactions of thomsonite have also been made. Thomsonite has been recognized from four new localities. Chemical, optical, and X-ray studies of gonnardite have shown it to be an independent species though closely related to thomsonite. It is suggested that it may be identical with the high-temperature form of thomsonite (the metathomsonite of F. Rinne). Larson's optical data for gonnardite are shown to refer to thomsonite, while there is an error of sign in the description of Lacroix. The space group of gonnardite could not be determined, but its unit cell, slightly larger than the pseudo-cell of thomsonite, appears to contain approximately $Ca_2Na_4Al_5Si_{15}O_{40}\cdot 14H_2O$. For Part III see *Ceram. Abs.*, **12** [9], 340 (1933). A.K.

Ilmenite-apatite deposits of west-central Virginia. C. W. RYAN. *Econ. Geol.*, **28** [3], 266–75 (1933).—Deposits of ilmenite, apatite, and mafic minerals recently discovered in Virginia are discussed with regard to their geological features, characteristics effecting mechanical recovery, and their possible economic importance. The ores show 20.73% TiO_2. In recent years the domestic consumption of ilmenite was 25,072 short tons in excess of the small tonnage produced in this country. Most of this came from India. The Virginia deposit is sufficient to supply the entire domestic market for a great many years. J.L.G.

Manganese deposits of Postmasburg, South Africa. ALEX. L. DU TOIT. *Econ. Geol.*, **28** [2], 95–122 (1933).—The main output has so far been exported principally to America and Japan. Geological structure, features indicating replacement, the process of replacement, the ores, their diastrophic aspect and their mining, and a bibliography are included in the article. Illustrated by maps, sections, and photomicrographs. J.L.G.

BOOK

The Geological Sciences and Theory of the Colloidal State. (Les Sciences Géologiques et la Notion d'État Colloïdal.) P. URBAIN. Hermann et Cie, Paris, 1933. 61 pp. Price 18 F. *Jour. Amer. Chem. Soc.*, **55** [8], 3508 (1933). F.G.H.

BOOK REVIEW

Minerals Yearbook. Dept. of Commerce, U. S. Bureau of Mines, Washington, D. C., 1933. 819 pp. Price $1.25, Supt. of Documents, Govt. Printing Office, Washington, D. C. In the first issue of the "Minerals Yearbook" the U. S. Bureau of Mines announces a change in the method of presenting statistics and economic discussions on minerals. This volume, bearing the date 1932 to 1933, furnishes timely statistical information regarding all commercially important minerals. It takes the place of "Mineral Resources of the United States," which has been issued annually for over half a century, and presents a statistical and economic résumé of conditions in the mineral industries that is of practical value in the task of recovery in these basic industries that employ more than 1,700,000 men and furnish over half the tonnage handled by railroads. During the 5-year period 1925 to 1929, when world output of minerals surpassed in quantity and value that of any other equal period in history, the total value was approximately 70 billion dollars, the annual average being about 14 billion dollars. In 1930 this total annual value dropped to about $12^1/_2$ billion dollars, 89% of the average for the preceding 5-year peak period. In 1931 the total fell to about 9 billion dollars; in 1932 the value of world mineral production was roughly 7 billion dollars, one-half the yearly average from 1925 to 1929. Domestic mineral production had a total value of about 29 billion dollars from 1925 to 1929, a yearly average of approximately 5.7 billion dollars. In 1930 it was 4.8 billion dollars; in 1931 the total had fallen to 3.2 billion dollars. For 1932 our mineral production was worth about 2.4 billion dollars, a decrease of around

57% from the average value for the 5-year period. Of the three main groups of minerals, the general recession has affected metals and mineral fuels least. Fifty-nine authors, all on the Bureau staff, contributed to the 61 economic and statistical surveys in this volume. There is about an equal amount of descriptive text, charts, and tables. The cloth binding is distinctive and the volume provides the mineral industries with adequate data in more convenient form at an earlier date than elsewhere or heretofore available. The Govt. Printing Office is in no way connected with the Bureau of Mines and no money derived from sales reverts to the Bureau.

PATENT

Process of treating bentonite, etc. J. D. HASEMAN. U. S. 1,929,113, Oct. 3, 1933. The method of treating bentonite comprises disintegrating damp bentonite, washing it, treating it with hydrochloric acid, washing it, treating it with sulfuric acid and washing it almost free of acid and alum, drying, and pulverizing it on a large scale.

Chemistry and Physics

Notes on the X-ray diffraction patterns of mullite. E. POSNJAK AND J. W. GREIG. *Jour. Amer. Ceram. Soc.*, **16** [11], 569–83 (1933).

Determination of potassium by sodium cobaltinitrite. J. E. SCHUELER AND R. P. THOMAS. *Ind. Eng. Chem., Anal. Ed.*, **5** [3], 163–65 (1933).—The advantages and disadvantages of these methods and of the procedure proposed by the authors are discussed. F.G.H.

Determination of potassium in silicates with a cobalt nitrite complex containing silver. I. V. TANANAEV. *Trans. Ukrainian Sci. Research Inst. Bldg. Materials* [U.S.S.R.], No. 10, 33 pp. (1931).—The purpose of this research work was to find a rapid, relatively cheap method having a 2% degree of accuracy. The following methods were investigated: (1) with sodium cobalt nitrite ($Na_3Co(NO_2)_6$), (2) with cobalt nitrite of lead and sodium, and (3) with cobalt nitrite of silver and sodium. Literature on this subject is cited. Detailed instructions to determine potassium in silicates are appended. S.I.P.

Determination of potassium by titration of the cobaltinitrite with permanganate. P. L. HIBBARD AND P. R. STOUT. *Jour. Assn. Official Agric. Chem.*, **16**, 137–40 (1933).—A standard procedure is described, with special equipment for filtering and washing the precipitate. H.H.S.

Spectroscopic determination of alkaline metals in micas by means of acetylene air flame. A. K. RUSANOV. *Mineral. Suir'e*, **8** [4], 21–27 (1933).—The mineral should be finely powdered. Directions for powdering are given. M.V.K.

Spectroscopic determination of lithium. A. K. RUSANOV. *Mineral. Suir'e*, **8** [4], 27–32 (1933).—Apparatus employed to determine lithium in solutions and micas is described. M.V.K.

Accelerated method of determining Me_2O_3, CaO, and MgO in silicates. A. K. BABKO. *Trans. Ukrainian Sci. Research Inst. Bldg. Materials* [U.S.S.R.], No. 10, 7 pp. (1931).—This is a continuation of previous work on the determination of silicon dioxide in silicates (*Ceram. Abs.*, **11** [2], 139 (1932)). It should be noted that the expression Me_2O_3 includes two oxides, Al_2O_3 and Fe_2O_3. After a brief review of literature on this subject the authors describe experiments and outline the procedure of the acceleration method using HF and H_2SO_4 to disintegrate the silicate. S.I.P.

Volumetric analytical determination of alkali metals in silicates. A. K. BABKO. *Trans. Ukrainian Sci. Research Inst. Bldg. Materials* [U.S.S.R.], No. 10, 5 pp. (1931).—After a description of the defects of the classical methods of determination of alkali metals in silicates by Berzelius and Smith, B. describes his own experiments and as a result of which the following method is proposed: The silicate is decomposed by hydrofluoric acid in a platinum dish and is evaporated to dryness on a water bath. To the dry residue, consisting of a mixture of fluorides and silico-fluorides, are added water and calcium oxide, and it is warmed not less than 30 min. CaF_2 and hydroxides of the other elements are formed. It is then filtered and washed with a hot concentrated solution of $Ca(OH)_2$. In the filtrate is precipitated the dissolved $Ca(OH)_2$ with ammonium carbonate and ammonia and it is evaporated to dryness; the excess of $(NH_4)_2CO_3$ is volatilized. It is then leached with water, the small precipitate of $CaCO_3$ is filtered off, and the carbonates of alkali metals are titrated with 0.1 *N* hydrochloric or nitric acid. The average error of this method in comparison with the gravimetric method is claimed to be not more than 0.1%. The duration of the determination is about 3 hr. See preceding abstracts. S.I.P.

Determination of metals by 8-hydroxyquinoline ("Oxine"). I. Effect of p_H. H. R. FLECK AND A. M. WARD. *Analyst*, **58**, 388–95 (1933).—The effect of p_H in acetate solutions on the precipitation and separation of Mg, Zn, Co, Ni, Cu, and Mo is described. H.H.S.

General method of quantitative microchemical analysis. I. Determination of calcium. L. T. FAIRHALL AND RUTH G. HOWARD. *Jour. Roy. Microscop. Soc.*, **53** [303], 129–39 (1933).—With this method calcium was satisfactorily determined in volumes of solutions as small as 0.1 cc. G.R.S.

Determination of calcium in mixtures containing phosphate. V. W. MELOCHE, L. E. CLIFCORN, AND W. B. GRIEM. *Jour. Assn. Official Agric. Chem.*, **16**, 240–45 (1933).—A precipitate free from Al, Fe, Mn, and Mg on the one hand and from phosphate on the other is obtained by precipitating Ca with oxalic acid in an acid medium (p_H2). H.H.S

Rapid method for determining aluminum in ores, grog, and clays by means of the ortho-oxyquinoline. V. VOZNESENSKIĬ AND S. ZHUKOVSKAYA. *Stal*, **3** [1–2], 116–20 (1933).—The method is based on the investigations of Berg (*Z. anal. Chem.*, **71**, 369 (1927); also *Ceram. Abs.*, **10** [8], 606–607 (1931)) and Han and Fiveg (*Z. anal. Chem.*, **71**, 122 (1927)) who determined aluminum in pure salts by means of ortho-oxyquinoline. Using the latter as a precipitant, aluminum may be determined volumetrically in the presence of silica; this is based on the property of ortho-oxyquinoline to brominate in an acid solution. The method of determination is discussed in detail. M.V.K.

Determining fluorine. P. MONGNAND. *Compt. rend.*, **194**, 1507 (1932); abstracted in *Sprechsaal*, **66** [26], 439 (1933).—The solution, whose F content must correspond to 0.4 g. CaF_2, is evaporated and treated with 4 cc. of a $CaCl_2$ solution. The gelatinous deposit is centrifuged, decanted, boiled with 5 cc. of a saturated $CaCl_2$ solution, and centrifuged after cooling. The operation is repeated; the solution is washed by centrifuging with water, rinsed with a little water on a filter, and the usual procedure is followed. See also *Ceram. Abs.*, **11** [1], 58 (1932), and following abstract. M.V.K.

Determination of fluorine. O. B. WINTER AND L. BUTLER. *Jour. Assn. Official Agric. Chem.*, **16**, 105–107 (1933).—Willard and Winter's method (volatilization as H_2SiF_6 and titration with thorium nitrate using zirconium alizarin as indicator) is subjected to examination with regard to the recovery of F from the sample. H.H.S

Report on analysis of fluorine compounds. G. A. SHUEY. *Jour. Assn. Official Agric. Chem.*, **16**, 153–55 (1933).—Willard and Winter's method is approved for rapid analysis. H.H.S.

Combination of water in the kaolin molecule. H. HIRSCH AND W. DAWIHL. *Ber. deut. keram. Ges.*, **14** [3], 97–105 (1933); for abstract see *Ceram. Abs.*, **12** [10–11], 402 (1933). E.J.V.

Optics in the service of ceramics. MAX PULFRICH. *Ber. deut. keram. Ges.*, **14** [7], 302–21 (1933).—Optical methods and apparatus used for determining some properties of ceramic products, raw materials, and constituents are described. References to literature are given. M.V.K.

Scientific considerations on silicate chemistry and its significance for practice. L. STUCKERT. *Emailwaren-Ind.*, **10** [9], 69–72 (1933).—A discussion of the works of Seger and Winkelmann and Schott, Gibbs' phase rule, the question of eutectics in enamels, and the problems of the state of glass is given. M.V.K.

Grain size measurements of kaolins and clays. HEIKEL VINTHER AND M. L. LASSON. *Ber. deut. keram. Ges.*, **14** [7], 259–79 (1933).—The apparatus of Andreasen is the best sedimentation apparatus, measuring from 0.5μ to 20μ. For exact measurements it should be attached to a thermostat. Köhn's assumption that a spherical volume is removed with a pipette is not valid with slow suction. The pretreatment of the samples is of great importance. A prolonged shaking with a peptizer is necessary. Several peptizers were investigated: Na_2CO_3, ammonia, Li_2CO_3, potassium citrate, potassium silico-tungstate, and sodium pyrophosphate, the latter being the best (0.002 m). Tuorila's criterion is insufficient for complete peptizing. A practical time scale for sampling with the Andreasen apparatus and standard working method for kaolins and clays are given. A new sedimentation apparatus for measuring in the range from 0.13μ to 0.5μ is described together with an altitude installation and a sucking contrivance. Characteristics for a series of different kaolins and refractory clays are defined and the significance of these characteristics in identification method and in problems of plasticity is discussed. M.V.K.

Investigations on clay suspensions. RENÉ DUBRISAY. *Céramique*, **36** [540], 49–55 (1933).—The velocity of settling begins to diminish with the addition of the hydrogen ion, passe.. a minimum at a p_H of 11–12, and then becomes larger. The stability

of suspensions always depends upon the reaction of the medium. Variations in the volume of deposit are found only in materials having a lamellar structure. Industrial applications in clay slip control and in rapid identification of clay by sedimentation curves are discussed. M.H.B.

Theory of artificial drying, calculating the characteristic elements, thermal balance, and control of an artificial drying installation. G. BARBEROT. *Rev. mat. constr. trav. pub.*, No. 287, pp. 144–47*B* (1933).—A discussion of drying from the ceramic point of view is given. Tables and diagrams illustrate the discussion. For previous abstract see *Ceram. Abs.*, **12** [10–11], 386 (1933). M.V.K.

Drying of solids. Diffusion equations for the period of constant drying rate. E. R. GILLILAND AND T. K. SHERWOOD. *Ind. Eng. Chem.*, **25** [10], 1134–36 (1933).—Equations are presented for moisture distribution in a solid slab during the period of drying at a constant rate. Calculated and experimentally determined results for two tests on the drying of a brick clay mix are compared and discussed. Illustrated with graphs. See also *Ceram. Abs.*, **11** [10], 541 (1932); **12** [3], 132 (1933). F.G.H.

Dimensional changes of clay ware during firing. II. TOSAKU YOSHIOKA. *Jour. Soc. Chem. Ind.* [Japan], **36** [6], 308–309*B* (1933).—The dimensional changes of (1) clay, (2) clay-quartz mixtures, (3) clay-feldspar, and (4) clay-quartz-feldspar mixtures were investigated. Clay generally displays (*a*) gradual slight expansion from 20 to 500°, (*b*) slight contraction from 500 to 900°, (*c*) sharp contraction from 900 to 950°, (*d*) sharp shrinkage from 1050 to 1200°, and (*e*) small contraction from 1200 to 1300°. See also *Ceram. Abs.*, **11** [9], 503 (1932). M.V.K.

BOOKS

Phase Rule Studies. Introduction to the Phase Theory. J. E. W. RHODES. Oxford Univ. Press, London, 1933. x + 131 pp. Price $2.25. Reviewed in *Jour. Amer. Chem. Soc.*, **55** [9], 3902–3903 (1933); *Ind. Eng. Chem.*, **25** [10], 1181 (1933).—Numerous systems of mineralogical interest are discussed in this introduction to the field of the phase rule. F.G.H.

Practicum of Chemical Analysis with X-Rays. (Praktikum der chemischen Analyse mit Röntgenstrahlen.) G. v. HEVESY AND E. ALEXANDER. Akademische Verlagsges., Leipzig, 1933. vi + 80 pp. Price 3.80 Rm. *Jour. Inst. Metals*, **53** [7], 422 (1933); see also *Ceram. Abs.*, **12** [10–11], 404 (1933). F.G.H.

X-Ray Analysis of Crystals. (Röntgenanalyse van Kristallen.) N. H. KOLKMEYER, J. M. BIJVOET, AND A. KARSSEN. D. B. Centen's Uitgevers Mij., Amsterdam. 170 pp. 2.60 f. Reviewed in *Rev. belge ind. verrières, céram., émail.*, **4** [7], 162 (1933).—This booklet is a compilation of six discussions dealing with (1) calculation of X-ray spectrograms, (2) results of X-ray examination of the structure of crystals, molecules, and atoms, (3) X-rays and organic chemistry, (4) some difficulties in the quantitative determination of the power of dispersion of atoms, (5) calculation of the structure of crystals by means of the Fourier analysis, and (6) course of determination of the structure by X-rays. M.V.K.

Tables for Calculation of Mineral and Rock Analyses. H. VON PHILIPSBORN. Price 28.00 Rm. Reviewed in *Analyst*, **58**, 429–30 (1933); for abstract see *Ceram. Abs.*, **12** [10–11], 398 (1933). H.H.S.

Inorganic Colloid Chemistry. Vol. I. Colloidal Elements. H. B. WEISER. John Wiley & Sons, Inc., New York, 1933. 389 pp. Price $4.50. *Jour. Amer. Chem. Soc.*, **55** [9], 3904 (1933). F.G.H.

Physical Methods of Analytical Chemistry. I. Spectroscopic and Radiometric Analysis. (Physikalische Methoden der analytischen Chemie. Teil 1. Spektroskopische und radiometrische Analyse.) Edited by W. BÖTTGER. Akademische Verlagsges., Leipzig, 1933. x + 388 pp. *Jour. Inst. Metals*, **53** [5], 283 (1933). F.G.H.

Qualitative Chemical Analysis. R. K. MCALPINE AND B. A. SOULE. Based upon the text of A. B. Prescott and O. C. Johnson. D. Van Nostrand Company, Inc., New York, 1933. xii + 696 pp. Price $4.50. Reviewed in *Jour. Amer. Chem. Soc.*, **55** [7], 3059–60 (1933); see also *Ceram. Abs.*, **12** [10–11], 403 (1933). F.G.H.

Calculations of Qualitative Analysis. C. J. ENGELDER. John Wiley & Sons, Inc., New York, 1933. Price $2.00. *Jour. Inst. Metals*, **53** [5], 283 (1933); see also *Ceram. Abs.*, **12** [6], 245 (1933). F.G.H.

Spectroscopy in Science and Industry. Introductory Manual Describing Its Applications to Industrial and Other Practical Problems. S. J. LEWIS. Blackie & Son, Ltd., London and Glasgow, 1933. vii + 94 pp. Price 3s 6d. *Jour. Inst. Metals*, **53** [7], 423 (1933); see also *Ceram. Abs.*, **12** [5], 205 (1933). F.G.H.

Physico-Chemical Handbook. (Physikalisch-chemisches Taschenbuch.) Edited by C. DRUCKER AND E. PROSKAUER. vi + 481 pp. Price 15 M. *Jour. Inst. Metals*, **53** [5], 283 (1933); see also *Ceram. Abs.*, **12** [8], 315 (1933). F.G.H.

English-German and German-English Dictionary of Chemistry. (Englisch-Deutsches und Deutsch-Englisches Wörterbuch der Chemie.) W. H. THUROW. Arthur Tetzlaff, Berlin-Schöneberg, 1933. x + 287 pp. *Jour. Inst. Metals*, **53** [5], 288 (1933). F.G.H.

PATENTS

Process for the production of boric acid from colemanite, etc. T. M. CRAMER AND G. A. CONNELL (Pacific Coast Borax Co.). U. S. 1,927,013, Sept. 19, 1933.

Process for the production of boric anhydride as boric acid from minerals containing both alkali and alkaline earth metals. T. M. CRAMER AND G. A. CONNELL (Pacific Coast Borax Co.). U. S. 1,927,014, Sept. 19, 1933.

Process for preparing alkali metal fluorides. MAX ZIMMERMANN (I. G. Farbenindustrie A.-G.). U. S. 1,927,108, Sept. 19, 1933.

Silicate gel manufacture. W. M. BRUCE (Permutit Co.). U. S. 1,928,123, Sept. 26, 1933. In the manufacture of a silicate gel by gelation of mixed solutions of sodium silicate and of one or more compounds of alumina with subsequent removal of water from the wet gel, a process comprises mixing solutions of the reagents in concentrations such as to cause immediate gel formation, malaxating the gel in its mother liquor during and after its formation, successively mixing with the malaxated gel solutions of the reagents of greater concentrations than those of the first mixed solutions, and malaxating the resulting mixed gel in the mother liquor to a uniform pulp.

Production of alkali metal aluminates. R. O. WOOD (National Aniline and Chemical Co., Inc.). U. S. 1,929,619, Oct. 10, 1933. (1) A process comprises calcining a commixture of an alumina sludge and an iron oxide sludge in the presence of an alkali metal carbonate. (2) A process for the production of alkali metal aluminate and of a product containing an activated iron oxide comprises calcining at a temperature of 650 to 900°C a commixture comprising an alumina sludge, an iron oxide sludge, and an alkali, treating the resultant calcined mass with water, and separating the solution of alkali metal aluminate thus obtained from the insoluble residual product which contains activated iron oxide.

Manufacture of aluminates. H. W. HEISER (Aluminum Co. of America). U. S. 1,930,271, Oct. 10, 1933. (1) A method of producing solid sodium aluminate from a reaction mixture substantially free from carbonaceous material comprises intimately mixing finely ground alumina with finely ground soda ash, incorporating in the mixture an inorganic bonding agent, moistening the mixture to a moldable consistency, forming briquets of the mixture, and heating the briquets to a temperature of between 900 and 1100°C. (2) A briquet consisting of alumina and soda ash bonded together by sodium aluminate is described. (3) A method of producing solid sodium aluminate of high purity and substantially free from insoluble material comprises intimately mixing 10 parts of finely ground purified aluminum hydrate and 8 parts of finely ground soda ash of chemically pure grade, adding thereto 35 parts of solid sodium aluminate, moistening the mixture with about 10 to 15% of water, forming briquets of the mixture thus treated, and heating the briquets to a temperature of between 900 and 1100°C.

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Effect of pressure on shrinkage during drying. A. N. AVGUSTINIK. *Keram. i Steklo*, **9** [6], 20–22 (1933).—The results are represented graphically. M.V.K.

Heat for drying brick. G. ZEHNER. *Tonind.-Ztg.*, **57** [68], 792–93 (1933).—Waste heat from the steam engine, heat radiated from the kiln, heat drawn from chambers in which the brick are cooling, and flue gases from the kiln and the boiler are discussed. W.M.C.

Experimental determination of the void content of close-packed mineral powders. R. N. TRAXLER, L. A. H. BAUM, AND C. V. PITTMAN. *Ind. Eng. Chem., Anal. Ed.*, **5** [3], 165–68 (1933).—Several commercial mineral powders were divided into five or six definite size fractions, and the void contents of the unfractionated powders and the various fractions were determined by three methods, (1) dry compaction, (2) liquid absorption, and (3) briquetting. For most of the powders the lowest void content values were obtained by the briquetting method. The data for limestone, silica, marble, and black slate powders indicate that particle size has no appreciable effect on the void content, but the results for trap rock and soapstone apparently do not agree with this generalization. The void content values of the various size fractions of powdered tripoli and argillaceous silica, minerals which possess peculiar characteristics, are discussed. Although texture has an effect on void content, regularity in particle shape is probably of greater importance. F.G.H.

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